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Major NASA Satellite Missions and Key Participants

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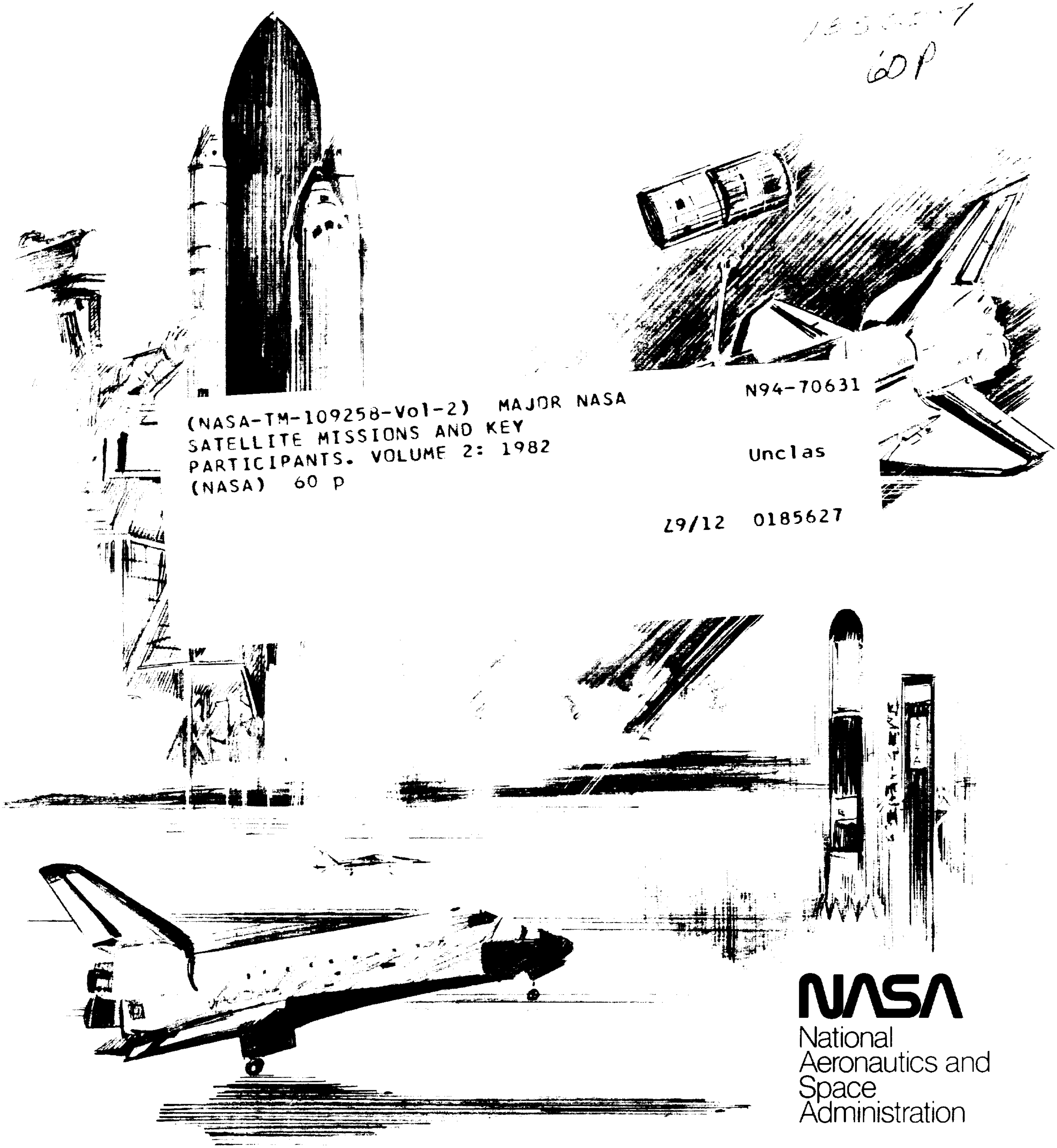

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NASA
National
Aeronautics and
Space
Administration

Introduction to Volume Number Two NASA Space Missions Since 1958

This volume continues a tradition, established by the NASA/Goddard Space Flight Center, of documenting within a single publication, NASA space missions since the beginning of the U. S. Space Program.

The data and supporting information have been gleaned from many sources. At times, there were conflicts in such data and value judgments had to be made. These evaluations are those of the author who, therefore, assumes responsibility for the material presented herein, and any corrections of facts will be greatly appreciated.

To Ms. Janet Wolfe, Jim Elliott, Carter Dove, Al Matelis and Mrs. Ellen Seufert, of the Goddard Public Affairs Office my grateful thanks for their support, assistance and editorial review.

It has been a privilege to have helped document the U. S. Space effort for the last twenty-five years. It was an exciting period made possible by courageous and creative people!

Alfred Rosenthal

RCA-D (SATCOM IV)

Launch Vehicle — A Delta 3910 launch vehicle consisting of a 2.4-meter (8-foot) first stage powered by a Rocketdyne RS-27 liquid-fueled engine; nine Thiokol Castor IV strap-on solid motors; a 1.5-m (5-foot) diameter second stage powered by a TRW TR-201 liquid fueled engine; and a 2.4-meters (8-foot) diameter fairing.

Spacecraft Description - The three-axis stabilized spacecraft was equipped with the power, attitude control, thermal control, propulsion, structure and command, ranging and telemetry necessary to support mission operations from booster separation through 10 years in geosynchronous orbit. Approximate dimensions of the spacecraft were 119 by 162 centimeters (47 inches by 64 inches) for the baseplate and 119 centimeters (46 inches) for the main body height. The spacecraft weight was 1081 kilograms (2,385 pounds)—within the Delta 3910/PAM useful load capacity of 1,088 kilograms (2,400 pounds). With solar panels deployed, the satellite spaned 11.2 m (37 feet). The spacecraft main body measured 1.6 by 1.27 by 1.27 m (5.2 by 4.1 by 4.1 feet). Spacecraft life, with continuous full power, designed to be 10 years.

The RCA-D Domestic Communications Satellite (RCA Satcom IV) was a 24-channel spacecraft to provide commercial communications to Alaska, Hawaii and the contiguous 48 states. It also was to distribute programming to the Nation's cable television systems.

RCA-D was to join three other RCA satellites, in orbit since 1975, 1976 and 1981 respectively. The satellites provided coverage for all 50 states and Puerto Rico with television, voice channels and high speed data transmission. There were more than 4,000 Earth stations with direct access to these spacecraft.

Spacecraft Payload — The 24-channel communication satellite consisted of a fixed, four-reflector antenna assembly and a lightweight transponder of high-efficiency traveling wave tube amplifiers (TWTA's) and low-density microwave filters. Graphite-fiber epoxy-composite was the basic material for the 24 input and output multiplex filters, as well as for waveguide sections and antenna feed.

Both horizontal and vertical polarizations were used in the communications subsystem for adjacent channel isolation. The communications antennas used grid reflectors allowing overlap of the horizontal and vertical reflector structures by positioning their grids perpendicular to each other. The transfer orbit omni antenna was attached to the communications antenna feedhorn support structure with its axis of symmetry along the spacecraft's transfer orbit spin axis. The synchronous orbit omni antenna was mounted on the antenna panel proper.

The hydrazine propellant tanks protruded from both the east and west panels. The passive nutation damper loop was affixed to the west panel. The two remaining main body panels supported the communication transponders and the housekeeping equipment, respectively. The solar array panels folded against the transponder and housekeeping panel faces when stowed for launch. The spacecraft was three-axis stabilized using momentum bias and magnetic attitude control. The spacecraft had seven functional subsystems: Communications (Transponder and Antenna), Command, Ranging, and Telemetry (CR&T), Attitude Control, Propulsion, Power, Thermal Control, Structure.

Project Results — The RCA-D mission, was launched from the Eastern Space and Missile Center, Pad 17A, on January 16, 1982. Both the launch vehicle and the PAM-D stages met all performance goals and provided the following set of orbit parameters:

Vehicle Transfer Orbits

	Second Stage		**PAM-D**	
	Predicted	**Actual**	**Predicted**	**Actual**
Apogee (km)	316.800	315.845	35,968.498	36,116.27
Perigee (km)	−771.050	−772.417	185.101	181.84
Inclination°	29.109	29.108	27.400	27.485

Major Participants:

NASA Headquarters

Dr. Stanley I. Weiss	Associate Administrator for Space Transportation Operations
Joseph B. Mahon	Director, Expendable Launch Vehicle Program
Peter Eaton	Manager, Delta
Robert E. Smylie	Associate Administrator for Space Tracking and Data Systems

Goddard Space Flight Center

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Ray Mazur	Mission Support

Kennedy Space Center

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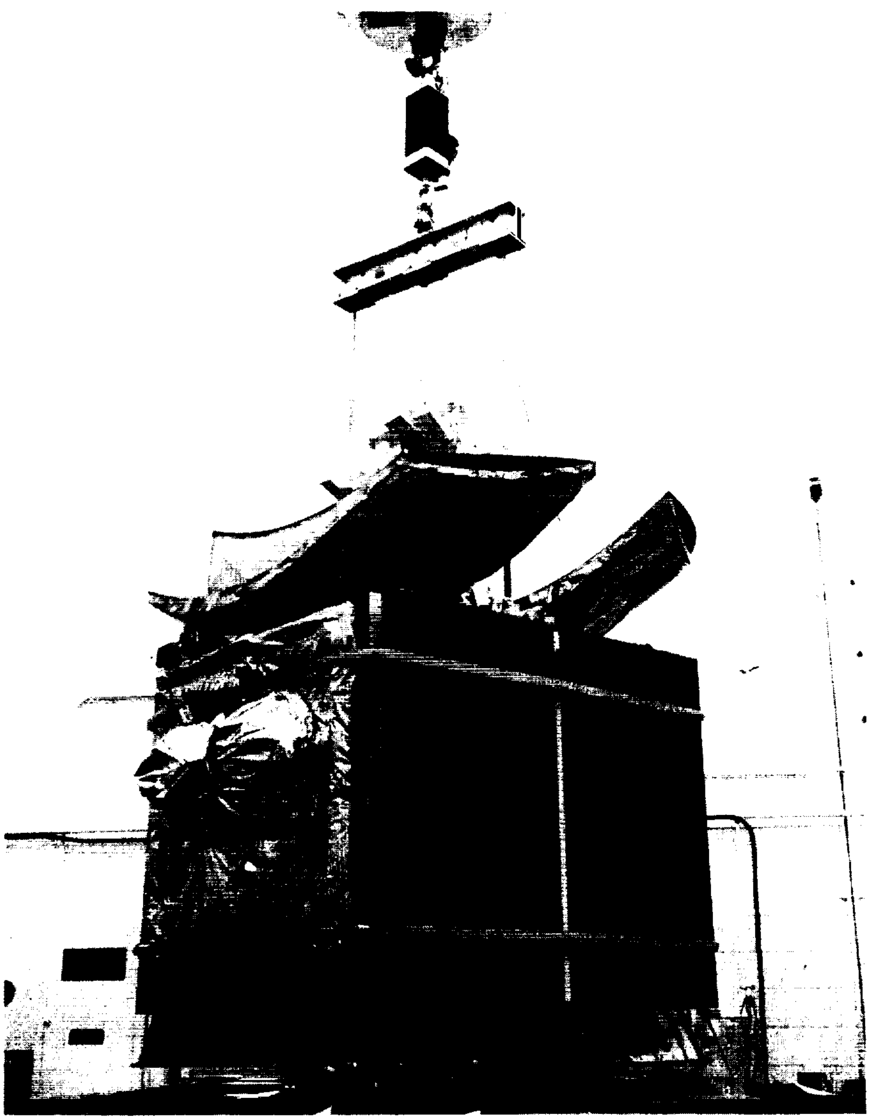
D. C. Sheppard	Chief, Automated Payloads Division

Wayne L. McCall	Chief, Delta Operations Division
Barry Olton	Spacecraft Coordinator

RCA American Communications, Inc.

John Christopher	Vice President of Technical Operations
Peter Plush	Manager, Major Programs and Technical Operations Services
Joseph Schwarzwe	Manager, Space Systems
William Palme	Manager, Major Programs, Launch Vehicle Integration
Joseph Elko	Manager, Spacecraft Engineering



Satcom IV, RCA's fourth communications satellite being prepared for launch on January 16, 1982.

WESTAR-IV

Launch Vehicle — A Delta 3910 launch vehicle 35 meters (116 feet) high and consisting of a 2.4-m (8-foot) first stage, powered by a Rocketdyne RS-27 liquid-fueled engine; nine Thiokol Castor IV strap-on solid motors; a 1.5-m (5-foot) diameter second stage powered by a TRW TR-201 liquid fueled engine; and a 2.4-m (8-foot) diameter fairing.

Spacecraft Description — The satellite was 274 centimeters (108 inches) in height in its stowed configuration and 684 centimeters (269 inches) in height when it was deployed in space. Diameter was 216 cm (86 inches). It weighed about 1,100 kilograms (2,425 pounds) in the transfer orbit after payload assist module burnout and approximately 585 kg (1,290 pounds) in the geosynchronous orbit after the apogee kick motor was fired.

Project Objectives — WESTAR IV joined three other Western Union satellites. WESTARs I and II were launched into geosynchronous orbit in 1974 and WESTAR III was placed in orbit in 1979. WESTAR IV had a design life of 10 years and was to relay voice, data, video and facsimile communications to the continental United States, Hawaii, Alaska, Puerto Rico and the Virgin Islands from a geosynchronous position of 99 degrees west longitude.

WESTAR I was positioned approximately on-line with San Antonio, Texas, at 99 degrees west longitude; WESTAR II was located on a line slightly west of San Francisco at 123.5 west longitude; and WESTAR III was positioned on-line with Baton Rouge, LA, at 91 degrees west longitude. WESTAR I and II were expected to reach the end of their design life in 1983 and 1984 respectively.

WESTAR IV and the planned WESTAR V, scheduled for launch in 1983, were to relay communications traffic previously carried on these two satellites.

Spacecraft Payload — WESTAR IV carried 24 transponder channels, twice the number of earlier WESTARs and developed 40 percent more transmitting power than most domestic communications satellites. It produced in excess of 800 watts of solar power. The spacecraft was double the size of WESTARs I, II, and III, and it had about four times the capacity.

Project Results — WESTAR IV payload was launched successfully from the Eastern Space and Missile Center at 7:04 p.m., EST, on February 25, 1982, by a Delta 3910 vehicle, mission number 160.

Performance of the two-stage Delta launch vehicle was nominal and placed the payload in a suborbital trajectory as planned. The Payload Assist Module which was part of the payload, also performed nominally. The synchronous transfer orbital elements achieved by Delta/PAM, compared with the nominal expected, are as follows:

	Expected	Measured
Apogee (km)	35,556	36,526
Perigee (km)	166	166
Inclination (degrees)	27.5	27.5

Goddard Space Flight Center

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David W. Grimes	Delta Project Manager
William A. Russell, Jr.	Deputy Delta Project Manager, Technical
John D. Kraft	Manager, Delta Mission Analysis and Integration
Richard H. Sclafford	WESTAR IV Mission Integration Manager
Robert I. Seiders	Mission Operations and Network Support Manager
Ray Mazur	Mission Support

Kennedy Space Center

Thomas S. Walton	Director, Cargo Operations
Charles D. Gay	Director, Expendable Vehicles Operations
D. C. Sheppard	Chief, Automated Payloads Division
Wayne L. McCall	Chief, Delta Operations Division
Barry Olton	Spacecraft Coordinator

Western Union

William Callanan	WESTAR Program Manager
Edward Levine	Director, Satellite Engineering
J. W. Van Cleve	Executive Consultant, Satellite Operations
F. W. Ziegler	Executive Consultant, Engineering
E. J. Minger	Director, Launch Services

Hughes Aircraft Co.

L. A. Gustafson	WESTAR Program Manager
C. T. McGee	Assistant WESTAR Program Manager
A. F. Berg	Manager, Launch Operations

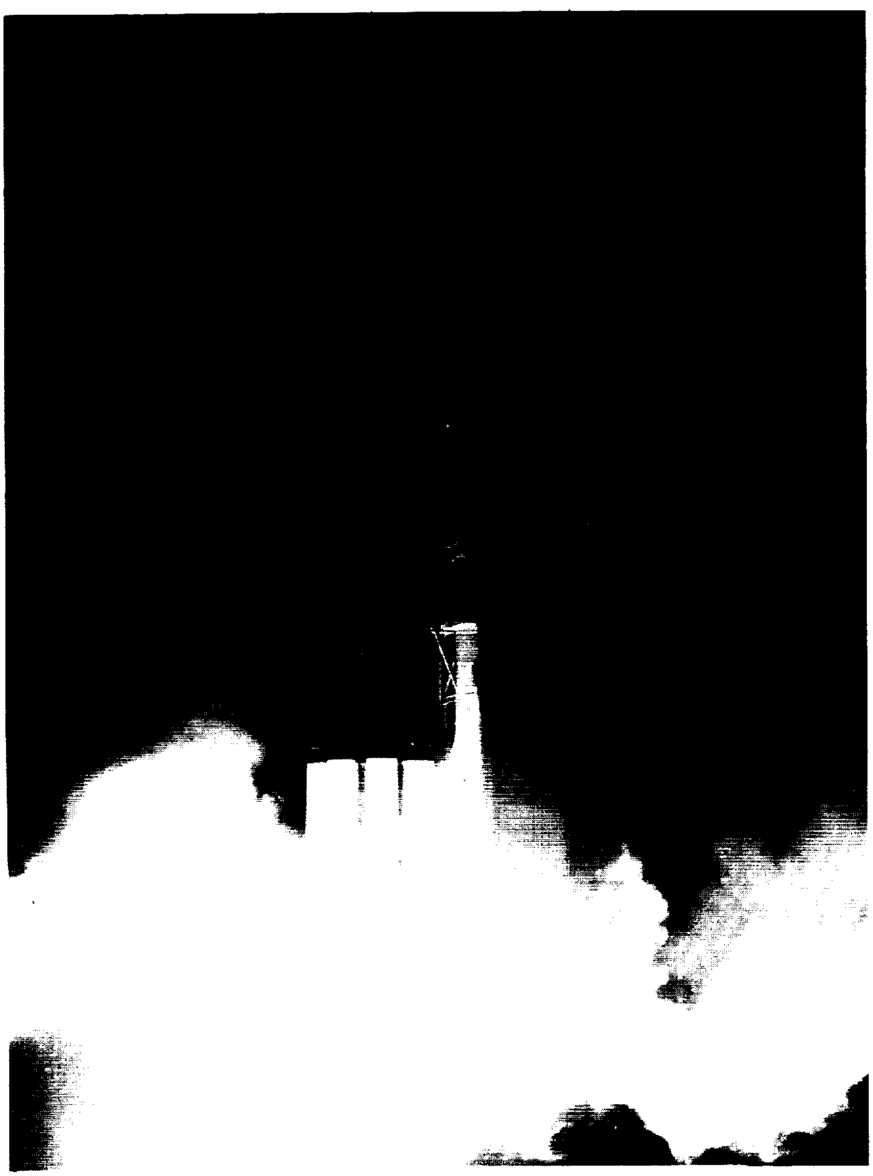
Contractors

Hughes Aircraft Co. Space Division Redondo Beach, CA	Spacecraft
Western Union Upper Saddle River, NJ	Spacecraft Management Development/Production
McDonnell Douglas Astronautics Co. Huntington Beach, CA	Delta Launch Vehicle and PAM-D Payload Stage

Rocketdyne Division Rockwell International Canoga Park, CA	First Stage Engine (RS-27)
Thiokol Corp. Huntsville, AL	Castor IV Strap-on Solid Fuel Motors
TRW Redondo Beach, CA	TR-201 Second Stage Engine
Delco Santa Barbara, CA	Guidance Computer

Major Participants:

Dr. Stanley I. Weiss	Associate Administrator for Space Transportation Systems
Joseph B. Mahon	Director, Expendable Launch Vehicle Program
Peter Eaton	Manager, Delta
Robert E. Smylie	Associate Administrator for Space Tracking and Data Systems



Delta 160 launches Westar IV, Western Union's communications satellite, into a geosynchronous orbit. February 25, 1982.

INTELSAT V-D

Launch Vehicle — Intelsat V-D was launched by the Atlas Centaur, NASA's standard launch vehicle for intermediate weight payloads. The launch vehicle had the following general characteristics:

Height: 40.8 meters (134 feet) including nose fairing

Diameter: 3.05 m (10 feet)

Total Liftoff Weight: 147,926 kg (326,120 pounds)

Liftoff Thrust: 1,917,088 newtons (431,000 pounds) sea level

Atlas Stage

The Atlas stage consisted of the booster section (one-half stage) and the sustainer/vernier section (first stage). The Atlas was manufactured by General Dynamics/Convair, San Diego, Calif., using the MA-5 engine system supplied by Rocketdyne Division of Rockwell International, Canoga Park, Calif. The MA-5 system consisted of two booster engines, one sustainer engine and two vernier engines. The Atlas stage had the following characteristics:

Height: 21.1 m (69.5 feet)

Diameter: 3.05 m (10 feet)

Propellants: RP-1 kerosene for fuel and liquid oxygen (LOX) as the oxidizer

Thrust: Total Booster: 1,645,750 Newtons (370,000 pounds) sea level
Sustainer: 266,880 N (60,000 pounds)
Total Vernier: 4,448 N (431,000 pounds)

Total Liftoff Thrust: 1,917,088 N (431,000 pounds)

Centaur Stage

The Centaur (second stage) was manufactured by General Dynamics/Convair, using the RL-10 engines built by Pratt and Whitney Aircraft Group, West Palm Beach, Florida. This stage had the following characteristics:

Height: 9.1 m (30 feet)

Diameter: 3.05 m (10 feet)

Propellants: Liquid hydrogen for fuel and liquid oxygen for the oxidizer

Thrust: 146,784 N (33,000 pounds) vacuum

Spacecraft Description —

Dimensions

- Solar Array (end to end) : 15.6 meters (51.1 feet)
- Solar Array (end to end) : 15.6 meters (51.1 feet)
- Main Body "Box" : 1.66 × 2.01 × 1.77 meters (5.4 × 6.6 × 5.8 feet)
- Height : 6.4 meters (21.0 feet)
- Width (fully developed) : 6.8 meters (22.25 feet)
- Weight (at launch, without MCS): 1,928 kilos (4,251 pounds)

General Characteristics —

- Three-axis body stabilized with Sun and Earth sensors and momentum wheel.
- Wing-like, Sun-oriented solar array panels producing a total of 1,241 watts of electrical power after 7 years in orbit.
- Modular construction.
- Seven-year expected life in orbit.

Project Objectives — The spacecraft almost doubled the communications capability of earlier satellites in the Intelsat series — 12,000 voice circuits and two color television channels. It was to be positioned in geosynchronous orbit over the Indian Ocean as the prime Intelsat satellite to provide communications services between Europe, the Middle East and the Far East.

The Intelsat global satellite system comprised two essential elements: the space segment, consisting of satellites owned by Intelsat, and the ground segment, consisting of Earth stations, owned by telecommunications entities in the countries in which they are located.

The space segment consisted of 10 satellites in synchronous orbit at an altitude of approximately 35,780 km (22,240 miles). Global service was provided through a combination of Intelsat IV-A and Intelsat IV satellites over the Atlantic, Indian, and Pacific Ocean regions.

The Intelsat IV-A had a capacity of 6,000 voice circuits and two television channels, while the Intelsat IV had a capacity of 4,000 voice circuits plus two television channels. The Intelsat V had a capacity of 12,000 voice circuits plus two television channels. The ground segment of the global system consisted of 295 communications antennas at 242 Earth station sites in 129 countries and territories.

The combined system of satellites and Earth stations provided more than 800 Earth station-to-Earth station communications pathways. In addition to the international voice circuits in full-time use (about 8,500), Intelsat provided a wide variety of telecommunications services, including telegraph, telex, data, and television to over 150 countries, territories, and possessions.

Spacecraft Payload — Intelsat V was the first Intelsat satellite to have the following features:

- Frequency reuse through both spatial isolation and dual polarization isolation.
- Multi-band communications — both 14/11 GHz and 6/4 GHz.
- Maritime communications subsystem (MCS).
- Use of nickel hydrogen batteries in later spacecraft.

In designing Intelsat V, engineers had to work within a number of limiting factors to achieve the communications capacity required. Typical of these were: limitations on the available frequency bands and the maximum mass which could be placed in orbit by the then (1973+) only available launch vehicle — Atlas Centaur.

These limitations were overcome with the result that each Intelsat V has twice the capacity of its predecessors. The extra capacity was derived by reusing the available frequency bandwidth — up to four times — and by utilizing another range of frequencies.

Contributions have been made to the design, development, and manufacture of Intelsat V by aerospace manufacturers around the world under the prime contractor, Ford Aerospace and Communications Corporation (FACC) of the United States.

Members of this international manufacturing team were:

- Aerospatiale (France)
- GEC-Marconi (United Kingdom)
- Messerschmitt-Bolkow-Blohm (Federal Republic of Germany)
- Mitsubishi Electric Corporation (Japan)
- Selenia (Italy)
- Thomson-CSF (France)

Each manufacturer concentrated on specific areas of the Intelsat program.

- Aerospatial (France) - Aerospatiale initiated the structural design that formed the main member of the spacecraft modular design construction. It supplied the main body structure thermal analysis and control.
- GEC-Marconi (United Kingdom) - Marconi produced the eleven GHz beacon transmitter used for Earth station antenna tracking.
- Messerschmitt-Bolkow-Blohm (Federal Republic of Germany) - MBB designed and produced the satellite's control subsystem and the solar array.
- Mitsubishi Electric Corporation (Japan) - Mitsubishi was responsible for both the 6 GHz and the 4 GHz Earth coverage antennas. It also manufactured the power control electronics and, from an FACC design, the telemetry and command digital units.
- Selenia (Italy) - Selenia designed and built the six telemetry, command, and ranging antennas, two 11 GHz beacon antennas and two 14/11 GHz spot beam antennas. It also built the command receiver and telemetry transmitter which combine to form a ranging transponder for determination of the spacecraft position in transfer orbit.
- Thomson-CSF (France) -Thomson built the 10 w, 11 GHz traveling wave tubes of which there are 10 per spacecraft.

All this was brought together by FACC through its Western Development Labs Division in Palo Alto, California. Ford was also responsible for the development of the satellite's communications package and for the development of the maritime communications subsystem (MCS) to be integrated into the fifth, sixth, seventh, eighth, and ninth Intelsat V satellites.

Project Results — The satellite was launched from Complex 36, Cape Canaveral, Florida, at 7:23 p.m., EST, on Thursday, March 4, 1982. It was the fourth of the Intelsat V series, which was successfully placed into the desired transfer orbit by Atlas Centaur vehicle AC-58, meeting all NASA objectives.

Orbital Parameters	Planned	Actual
Apogee* (km)	35,964	35,953
Perigee* (km)	166.6	165.8
Inclination (deg)	24.1315	24.1308
Eccentricity	.73225	.73218

*measured from Earth's surface

The apogee kick motor was fired successfully by Intelsat on March 7, placing the satellite into near geosynchronous orbit. After initial positioning for preliminary testing, the satellite was moved to be on station over the Indian Ocean.

Major Participants:

NASA Headquarters

Dr. Stanley I. Weiss	Associate Administrator for Space Transportation Operations
Joseph B. Mahon	Director, Expendable Launch Vehicles
F. R. Schmidt	Manager, Atlas Centaur Launch Vehicle

Lewis Research Center

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J. E. Patterson	Chief, Launch Vehicles Division
S. V. Szabo, Jr.	Deputy Chief, Launch Vehicles Division
Richard E. Orzechowski	Intelsat Mission Project Engineer

Kennedy Space Center

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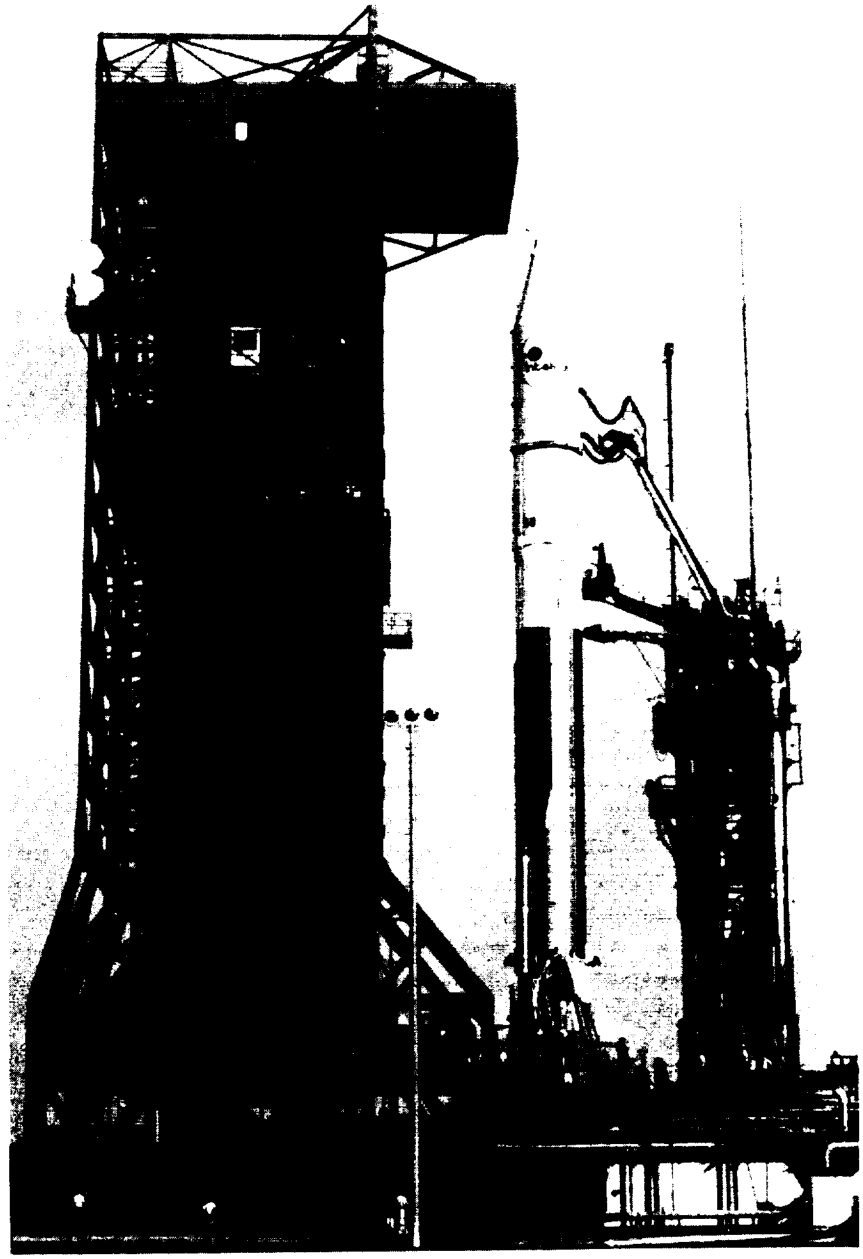
Charles D. Gay	Director, Expendable Vehicle Operations
D. C. Sheppard	Chief, Automated Payloads Division
James L. Womack	Chief, Atlas Centaur Operations Division
Larry Kruse	Spacecraft Coordinator
Andrea Caruso	Deputy Director, General Administration
Francis Latapie	Acting Deputy Director, General Administration
Allan M. McCaskill	Manager, Launch Vehicle Program Office

Contractors

General Dynamics/Convair San Diego, California	Atlas Centaur launch vehicle

Intelsat V-D was launched by this Atlas Centaur booster. It was the fourth in a series of nine such spacecraft placed in orbit to provide reliable, world wide telecommunications.



Honeywell Aerospace Division St. Petersburg, Florida	Centaur guidance intertial measurement group
Pratt and Whitney Aircraft Group West Palm Beach, Florida	Centaur RL-10 engines
Teledyne Industries, Inc. Northridge, California	Digital computer unit/PCM telemetry
Rocketdyne Division Rockwell International Corp. Canoga Park, California	MA-5 propulsion systems

STS-3

Project Objectives — Program overview, launch vehicle, spacecraft description, see STS-1. STS-3 liftoff weight was 2,031,619 kilograms (4,478,954 pounds) compared to an STS-2 liftoff weight of 2,030, 254 kg (4,475,943 lb.) — an increase of 1,365 kg (3,011 lb). Space Shuttle orbiter Columbia made its third voyage into space March 22, 1982, launched from Kennedy Space Center, Florida; it carried an array of astronomy and space science payloads (OSS-1) in its cargo bay.

Jack R. Lousma was STS-3 commander. He was on the second crew which manned the Skylab space station for 59 days in 1973. C. Gordon Fullerton was the pilot. Fullerton had not flown in space, but was teamed with Fred Haise in three of the five approach and landing glide flights of orbiter Enterprise in 1977.

Third of four planned orbital flight tests, STS-3 was to continue the engineering shakedown of the Space Shuttle with emphasis on measuring the thermal responses of the orbiter spacecraft during long periods of nose-to-Sun, tail-to-Sun, and open payload-bay-to-Sun.

The Canadian-built remote manipulator arm was to get its second workout, including grappling and hoisting two instrument packages from the payload bay to "sniff" the space environment around Columbia. The two instruments were to be nested back into their holddowns and return to Earth after serving as forerunners of future deployable payloads.

In addition, STS-3 carried an OSS-1 payload. It represented the most extensive and comprehensive scientific activity yet undertaken by the Shuttle. The STS-3 mission, building on the capability of the orbiter as a platform for remote sensing and scientific experimentation demonstrated on STS-2, evaluated the operation of the Shuttle under extreme thermal conditions. The scientific experiments on board also were to evaluate any effects that the orbiter would have on its immediate space environment. The investigations were designed to assist NASA in planning future scientific investigations using the Space Shuttle.

The STS-3 OSS-1 payload was dedicated to scientific investigations in space plasma physics, solar physics, astronomy, life sciences, and space technology. The payload was designated OSS-1 because the program originally was managed by the Office of Space Science (OSS) at NASA Headquarters.

The OSS-1 payload was described as the "Pathfinder Mission" because it would provide both technological and scientific information for future flights of the Shuttle and thus serve as a "pathfinder" for more extensive investigations of space.

Six of the nine experiments on OSS-1 were designed by scientists at five American universities and one university in Great Britain and operated under their supervision during the mission. One experiment was developed by the Naval Research Laboratory in Washington, DC, and two were developed at the Goddard Space Flight Center, which had been responsible for the development of the payload for NASA and for its integration with the pallet and the Shuttle orbiter. The U-shaped metal pallet, 2.86 meters (9.4 ft) by 4.3 m (14.2 ft), was built by the European Space Agency to fit into the Shuttle's 4.57 m (15 ft) high payload bay.

The space plasma physics experiments were the Plasma Diagnostics Package (PDP), a project of the University of Iowa, and the Vehicle Charging and Potential experiment (VCAP), from Utah State University.

The solar physics experiments were the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) — a Naval Research Laboratory project — and the Solar Flare X-Ray Polarimeter experiment (SFXP) conducted by scientists from Columbia University.

The astronomy investigations were the Shuttle Spacelab Induced Atmosphere (SSIA) — a University of Florida project — and the Microabrasion Foil Experiment (MFE) by the University of Kent, Canterbury, England. The life sciences project was a Plant Growth Unit (PGU) from the University of Houston, and the space technology projects were the Thermal Canister Experiment (TCE), and the Contamination Monitor Package (CMP), both from Goddard. The Contamination Monitor Package investigation was funded by the U.S. Air Force.

Additionally, a "Get Away Special" canister in the payload bay was evaluated for suitability as a container for small, self-contained low-cost payloads.

Orbiter systems, such as the space radiators, electrical power generating system, attitude control and life support underwent further performance measurements during the seven-day flight in the continuing qualification of the Space Transportation System for routine, operational space flight.

STS-3 was launched into a 38-degree inclination orbit circularized with two orbital maneuvering system (OMS) maneuvers at 240.8 kilometers (130 nautical miles). Orbital maneuvering system burns later in the flight were to have little effect upon the orbit for they were engineering tests of the engines in the cold-engine restart mode, simulating worst-case flight conditions for operating the engines.

Lousma and Fullerton again used wireless microphone-headsets flown on STS-2, freeing them from the restricting tethers of hardline cables.

The orbital maneuvering system deorbit burn was made over the Indian Ocean near the end of the 115th orbit. Columbia entered the atmosphere over the Western Pacific northeast of Guam. The groundtrack to landing was almost identical to Columbia's first two flights as it was to cross the California coast just north of Morro Bay.

Spacecraft Payload — Weights of payloads and experiments in the payload bay for STS-3 were as follows:

- OSS-1, 2,264.4 kg (4,992 lb);
- Spacelab pallet, 850.5 kg (1,875 lb);
- OSS-1 attach hardware, cabling, 377.4 kg (832 lb);
- Monodisperse Latex Reactor, 76.7 kg (169 lb);
- Aerodynamic Coefficient Identification Package, 125.6 kg (277 lb);
- Get-Away Special, 324.3 kg (715 lb);
- Electrophoresis Equipment Verification Test, 37.6 kg (83 lb);
- Induced Environment Contamination Monitor/Development Flight Instrumentation, 5.015 kg (11,056 lb); and
- Miscellaneous hardware, cabling, 586.9 kg (1,294 lb).

Total cargo weight was 9,658.5 kg (21,293 lb)

Project Results — Launched from Kennedy Space Center, Florida, on March 22, 1982,, and landed at the White Sands Test Facility, New Mexico, on March 30, 1982.

This was Columbia's third orbital test flight. STS-3 lasted more than eight days, made 129 Earth orbits, and covered a distance of 6.24 million kilometers (3.9 million miles). It was not only the longest but also the busiest and most demanding of the Space Shuttle test missions. Lousma and Fullerton accomplished nearly everything they set out to do. The third mission of NASA's Space Transportation System (STS) proved a major stride toward an operational spacecraft. Rogers Dry Lake bed in California's Mojave Desert (Edwards Air Force Base) was the primary landing field for the shuttle orbital flight tests. STS-1 and STS-2 missions landed there. But heavy rains had drenched the dry lake. Nobody could predict how long it would take Edwards runway surface to be dry enough to support Columbia's landing.

The best alternate landing site — Northrup Air Strip at White Sands, New Mexico — was chosen for the STS-3 landing. Like Edwards, Northrup Air Strip is a hard-packed desert floor.

The Northrup strip was sufficiently long and wide to provide the margin of safety needed until the characteristics of Columbia's aerodynamics and its new computer-based automatic landing system are fully tested.

Plans called for the STS-3 landing at 2:27 p.m. EST, March 29, 1982. But as Lousma and Fullerton were preparing their spacecraft for entry into the atmosphere on March 29, wind velocities rose sharply at White Sands. John W. Young, commander of STS-1 — Columbia's maiden flight — piloted a jet aircraft over the landing area. He measured winds much too high for Columbia and observed that a severe sand storm had cut visibility at the landing site to near zero. He radioed Mission Control, "I think we ought to knock this off." "We concur," Mission Control replied.

Just 39 minutes before they were scheduled to fire their braking rockets to descend from orbit, Lousma and Fullerton were "waved off." Lousma landed Columbia the next morning under clear skies and acceptable wind conditions.

Moving the landing site from Edwards to White Sands meant that facilities for processing Columbia after landing had to be set up at White Sands. Equipment and technicians needed for the landing were transported from Edwards to White Sands in 38 railroad cars forming two special trains.

STS-3 was the third of four planned orbital test flights, designed to eliminate as many difficulties as possible before the Shuttle goes operational. In STS-3 some problems proved bothersome but most turned out to be of minor concern. About seven minutes after launch, a sensor flashed a message that one of the three Auxiliary Power Units (APUs) on Columbia was overheating. The APUs swivel rocket engines during the launch phase and operate the rudder and elevons during the return through the atmosphere when the Shuttle flies as an aircraft.

The Shuttle Orbiter can operate adequately using only two of its three APUs during the ascent and re-entry modes. They are not used in orbit. During return to Earth on this mission all three units operated properly.

On March 23 Lousma and Fullerton discovered that Columbia had lost more than 35 of its 31,000 heat-protection tiles. Loss of the tiles did not endanger the spacecraft during re-entry, when temperatures reached more than 2,000 degrees F. The tiles became detached during launch. Engineers continued replacement procedures designed to prevent tile separation during the fourth test mission. An inspection of Columbia after it landed revealed that is had lost 36 full tiles and parts of 19 others.

Early in the mission the crew encountered space sickness, a balky toilet, and temperature control, and radio static problems that interfered with sleep. A thermostat difficulty kept the cabin either too warm or too chilly. Whenevei Columbia passed over a certain area of Asia, the crew's radio headsets crackled with static, waking the astronauts if they were attempting to sleep. The static has been attributed to a powerful radar station. Most troubles were corrected by the third day and the astronauts went about their tasks in good health and high spirits for the remainder of the eight-day mission.

On March 26, three of the communications links between Columbia and Earth were lost due to transponder malfunctions. Besides the remaining high power communications link, a backup FM radio and UHF voice circuit were still available. Loss of the radio links reduced data transmission from Columbia to the ground but did not threaten safety.

Major Participants

NASA Headquarters

James M. Beggs	Administrator
Dr. Hans Mark	Deputy Administrator
Maj. General J. A. Abrahamson	Associate Administrator for Space Transportation Systems

L. Michael Weeks	Deputy Associate Administrator for Space Transportation Systems
David R. Braunstein	Deputy Associate Administrator for Space Transportation System (Management)
Walter F. Dankoff	Director, Engine Programs
Edward P. Andrews	Director, Ground Systems and Flight Test
Frank Van Rensselear	Director, Upper Stages
Jerry J. Fitts	Director, Solid Rocket Booster and External Tank
Robert E. Smylie	Associate Administrator for Space Tracking and Data Systems

Johnson Space Center

Christopher C. Kraft, Jr.	Director
Clifford E. Charlesworth	Deputy Director
Glynn S. Lunney	Manager, Space Shuttle Program
Donald K. "Deke" Slayton	Manager, Orbital Flight Tests
Aaron Cohen	Manager, Space Shuttle Orbiter Project Office
George W. S. Abbey	Director of Flight Operations
Robert O. Piland	Director of Engineering and Development
Lynwood C. Dunseith	Director of Data Systems and Analysis

Kennedy Space Center

Richard G. Smith	Director
Dr. Robert H. Gray	Manager, Shuttle Projects Office
John J. Neilon	Manager, Cargo Projects
George F. Page	Director, Shuttle Operations
Thomas S. Walton	Manager, Cargo Operations

Marshall Space Flight Center

Dr. William R. Lucas	Director
Thomas J. Lee	Deputy Director
Robert E. Lindstrom	Manager, MSFC Shuttle Projects Office
James E. Kingsbury	Director, Science and Engineering Directorate
James B. Odom	Manager, External Tank Project

George B. Hardy	Manager, Solid Rocket Booster Project
James R. Thompson, Jr.	Manager, Space Shuttle Main Engine Project
James M. Sisson	Manager, Engineering and Major Test Management Office

The third Space Shuttle vehicle (STS-3) thunders aloft beginning a week-long mission. March 22, 1982.

Dryden Flight Research Facility

John A. Manke	Facility Manager
Gary Layton	Shuttle Project Manager

Goddard Space Flight Center

A. Thomas Young	Director
Dr. John H. McElroy	Deputy Director
Richard S. Sade	Director of Networks Directorate Space Tracking and Data Network
Walter LaFleur	Deputy Director of Networks Directorate (STDN)
William B. Dickinson	Division Chief, NASA Communications Network
Donald D. Wilson	Assistant Chief, NASA Communications Network
Daniel Spintman	Chief, Network Operations Division
James M. Stevens	Shuttle Network Support Manager

Key Spacecraft Personnel

OSS-1

PM	R. A. Kennedy	NASA Headquarters
PS	D. C. Eric Chipman	NASA Headquarters
MM	K. Kissin	NASA/GSFC
MS	W. M. Neupert	NASA/GSFC

Vehicle Charging and Potential Experiment (particles and fields)

PI	P. M. Banks	Stanford University
OI	W. J. Raitt	Utah State University
OI	P. R. Williamson	Utah State University
OI	R. M. Goldstein	NASA/JPL
OI	U. Samir	University of Michigan

Solar Ultraviolet Spectral Irradiance Monitor (solar physics)

PI	G. E. Brueckner	US Naval Research Laboratory
OI	J. D. F. Bartoe	US Naval Research Laboratory
OI	D. K. Prinz	US Naval Research Laboratory
OI	M. E. Van Hoosier	US Naval Research Laboratory

Influence of Weightlessness in Lignification of Peanut Seedlings (space biology)

PI	J. R. Cowles	University of Houston
OI	H. W. Scheld	University of Houston

Microabrasion Foil (interplanetary dust)

PI	J. A. M. McDonnell	University of Kent

Solar Flare X-ray Polarimeter Experiment (solar physics)

PI	R. Novick	Columbia University
OI	G. A. Chanan	Columbia University

Thermal Cannister Experiment (technology)

PI	S. Ollendorf	NASA/GSFC

Plasma Diagnostic Package (space plasmas)

PI	S. D. Shawhan	University of Iowa
OI	L. A. Frank	University of Iowa
OI	D. A. Gurnett	University of Iowa
OI	N. D'Angelo	University of Iowa
OI	H. C. Brinton	NASA/GSFC
OI	D. L. Reasoner	NASA/MSFC
OI	N. Stone	NASA/MSFC

Contamination Monitor

PI	J. J. Triolo	NASA/GSFC

Induced Atmosphere; Characteristics of Spacelab

PI	J. L. Weinberg	University of Florida
OI	D. W. Schuerman	University of Florida
OI	F. Giovane	University of Florida

Launch Vehicle — Delta 3910 launch vehicle, 35 meters (116 feet) high and a 2.4 m (8 ft) diameter first stage, powered by a Rocketdyne RS-27 liquid-fueled engine; nine Thiokol Castor IV strap-on solid motors; a 1.5 m (5 ft) diameter second stage powered by a TRW TR-201 liquid fueled engine; and a 2.4 m (8 ft) diameter fairing.

Spacecraft Description — Principal features included:

- Body stabilized design
- Two operating wheels, momentum bias system
- Single wing-deployable solar array
- Tow deployable antenna reflectors, C-band odd transmit/receive, and C-band even/S-band transmit
- Omnidirectional TT&C antenna coverage
- Bipropellant propulsion system for attitude control, stationkeeping and apogee burn maneuvers
- Two-axis scanning radiometer (VHRR) with 20-Centimeter (8-inch) diameter optics and passive radiation cooler
- Nondeployed configuration compatible with 2.4-meter (8-foot) Delta fairing and vertical mount in STS cargo bay
- Approximate mass 1,152 kilograms (2540 pounds) into transfer orbit

The principle geometry of the INSAT satellite were:

Satellite (stowed)	272 × 180 × 155 cm (107 × 71 × 61 inches)
Overall spacecraft envelope (with PAM-D)	256 cm (100.88 in) above separation plane 218 cm (86 in) diameter
Satellite (antennas, array and sail, deployed)	584 × 1793 × 138 cm (230 × 706 × 54.5 in)

Project Objectives — India's INSAT 1A multipurpose telecommunications/meterology spacecraft was to have a capability for nationwide direct broadcasting to community TV receivers in rural areas. Its orbital location was to be 74 degrees East Longitude above the Earth's Equator. Sister spacecraft INSAT-1B, scheduled for a July 1983 launch on Space Shuttle, was to occupy a similar equatorial location at 94 degrees East Longitude. Both spacecraft were built by Ford Aerospace and Communications Corporation under a joint venture of India's Department of Space, the Posts and Telegraphs Department (P&T) of the Ministry of Communications, the India Meterological Department of the Ministry of Tourism and Civil Aviation, and the Doordarshan of the Ministry of Information and Broadcasting.

The INSAT-1 meterological ground segment facilities included:

- A Meterological Data Utilization Center at new Delhi for processing INSAT-1 VHRR and data collection platform data which was received at the Delhi Earth Station and transmitted to the meterological center realtime over a microwave link.

- Secondary Data Utilization Centers located in various forecasting offices of the India Meteorological Department received processed images from the Meteorological Data Utilization Center over telecommunications lines.
- About 100 data collection platforms deployed all over the country, including some over oceans, and disaster warning facility.
- The Meteorological Data Utilization Center had facilities for processing, analysis, and storage of INSAT 1 Very High Resolution Radiometer and Data Collection Platform data. Each Data Collection Platform shall be capable of handling 10 sensors. The primary meterological sensors associated with the platforms were: air temperature, wet bulb temperature and relative humidity, wind speed, wind direction, atmospheric pressure, platform housing temperature, rainfall, sunshine and sea surface temperature.

Spacecraft Payload — The INSAT 1A and 1B system concept requires the spacecraft segment to include 12 transponders operating at 5935-6424 MHz (Earth-to-satellite), 3710-4200 MHz (satellite-to-Earth) for thick route, thin route, and remote area communication, and TV program distribution; and 2 transponders operating in 5855-5935 MHz (Earth-to-satellite) and 2555-2635 MHz (satellite-to-Earth) for direct TV broadcasting to augmented low cost community TV sets in rural areas, radio program distribution, national TV networking, and disaster warning.

A Very High Resolution Radiometer (VHRR) instrument with visible (.55 - .75 micron) and infrared (10.5 - 12.5 micron) channels with resolutions of 2.75 km and 11 km, respectively, and with full Earth coverage was included in the satellite to provide full frame image every 30 minutes for round-the-clock, half-hourly synoptic observations of weather systems including cyclones over India and the adjoining land and sea areas, sea surface and cloud-top temperatures, water bodies and snow-mapping as well as collection and transmission of meteorological, hydrological, and oceanographic data from unattended remote automatic data collection platforms (DCPs) to a central data processing center.. This permits timely warning of impending disasters from cyclones, floods, etc., and dissemination of meteorological information for agricultural and other purposes. Using the INSAT TV capability, the warnings would directly reach the population in the areas likely to be affected.

A data channel was provided for relay of meteorological, hydrological, and oceanographic data from unattended land and ocean-based data collection transmission platforms.

The telecommunications component provides over 8,000 two-way long distance telephone circuits potentially accessible from any part of India.

The television component of the INSAT-1 system included:

- Direct TV broadcasting to augmented community TV receivers in rural areas for which direct TV broadcast coverage has been identified as more economical
- Nationwide TV coverage in one step
- National networking of terrestrial TV transmitters
- Radio program distribution

Project Results — Delta 161, the INSAT 1A mission, was launched from the Eastern Space and Missile Center, Pad 17A, on April 10, 1982.

Both the launch vehicle and the PAM-D stages met all performance goals and achieved the following set of orbit parameters:

INSAT-1A Vehicle Transfer Orbits

	Second Stage		PAM Stage	
	Predicted	Actual	Predicted	Actual
Apogee (km)	259.496	259.305	35,995.243	35,312.12
Perigee (km)	−480.841*	−479.762*	166.655	165.37
Inclination°	30.139	30.137	28.400	28.289

*Planned Impact

Launch was delayed 2 days from the originally planned date by separate incidents. The first resulted in a one day delay when replacement of the solar sail on the spacecraft requiring removal and replacement of the fairing. The second also caused a one day delay when the ARIA tracking support aircraft could not take off due to mechanical difficulties.

Major Participants

NASA Headquarters

Dr. Stanley I. Weiss	Associate Administrator for Space Transportation Operation
Joseph B. Mahon	Director, Expendable Launch Vehicles
Peter Eaton	Program Manager, Delta
R. E. Smylie	Associate Administrator for Space Tracking and Data Systems

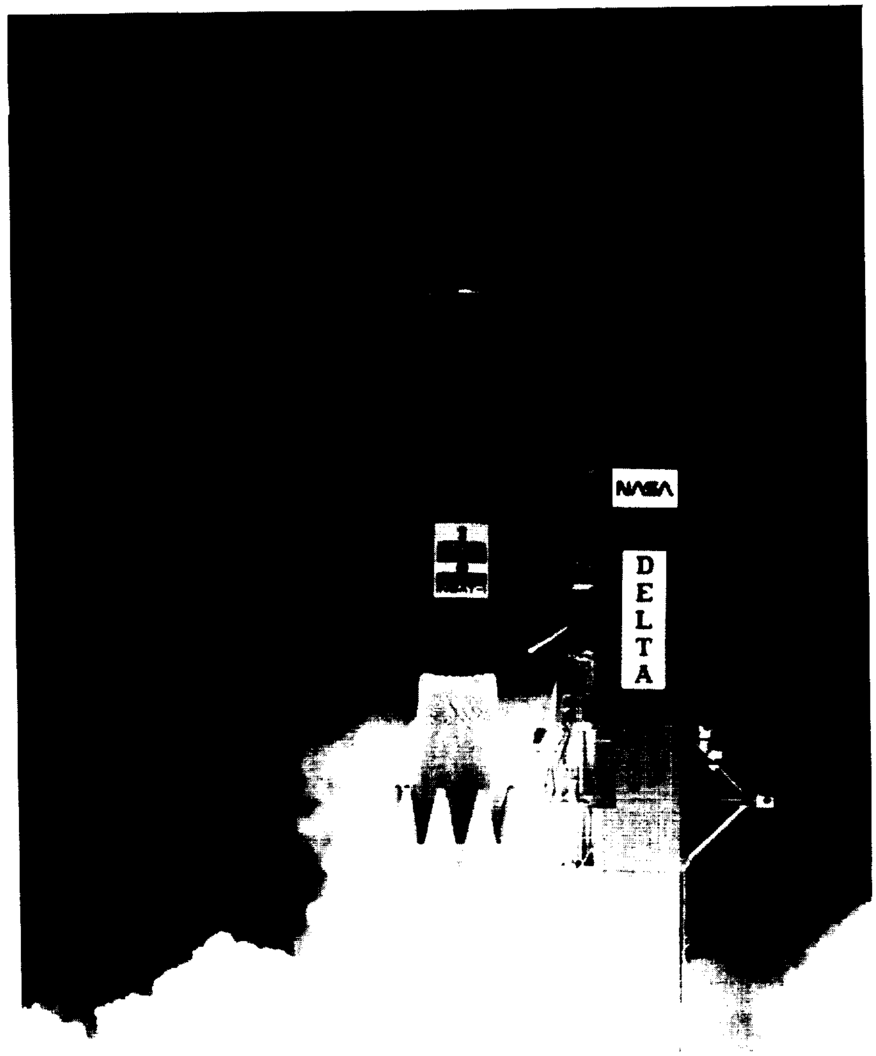
Goddard Space Flight Center

William C. Keathley	Director, Flight Projects Directorate
David W. Grimes	Delta Project Manager
William A. Russell, Jr.	Deputy Project Manager
John D. Kraft	Manager, Delta Mission Analysis and Integration
Philip B. Frustace	INSAT Mission Integration Manager
Robert I. Seiders	Mission Operations and Network Support Manager
Ray Mazur	Mission Support

Kennedy Space Center

Richard G. Smith	Director
Thomas S. Walton	Director, Cargo Operations
Charles D. Gay	Director, Expendable Vehicles Operations
D.C. Sheppard	Chief, Automated Payloads Division
Wayne L. McCall	Chief, Delta Operations Division
David Bragdon	Spacecraft Coordinator

India's Insat 1A communications satellite during its Delta launch on April 10, 1982.



Department of Space, Government of India (INSAT 1 Space Segment Project)

Professor S. Dhawan	Chairman, Space Commission
Professor U. R. Rao	Chairman, INSAT 1 Space Segment Project Board
Mr. P. P. Kale	Project Director, INSAT 1 Space Segment Project
Professor J. P. Singh	Program Director, INSAT Program Office
Dr. S. Vasantha	Deputy Project Director, INSAT 1 Space Segment Project

WESTAR V

Launch Vehicle — Delta 3910, 35.5 meters long (116 ft), including the spacecraft shroud. Liftoff weight was 190,630 kg (420,269 lb) and liftoff thrust was 2,058,245 newtons (547,504 lb), including the startup thrust of six of the nine solid motor strap-ons.

The first stage booster was an extended long-tank Thor powered by the Rocketdyne RS-27 engine system which used hydrazine (RP-1) and liquid oxygen propellants. Pitch and yaw steering was provided by gimballing the main engine. The vernier engine provided roll control during powered flight and control during coast.

Spacecraft Description — The spacecraft had two concentric, telescoping cylindrical solar panels. The outer panel was deployed after the satellite was placed in synchronous orbit, doubling the solar cell area of satellites with comparable diameter. With the outer panel extended, the spacecraft was to generate 684 watts of power at end of life.

The WESTAR V spacecraft has in common with the other Hughes' spin stabilized (HS 376) satellites, its telemetry, command, propulsion subsystem, spinning section, and apogee motor (Thiokol Star 30). Its power system was similar to previous Hughes designs and incorporates improved K-7 solar cells, providing 20 mW/cm2. Two 19 A-hr nickel cadmium batteries supplied full power service during eclipse operation for 10 years.

Heat generated by the electronics equipment was radiated into space through a thermal radiation band around the middle of the satellite. In WESTARs I, II, and III, heat was radiated through the end of the cylindrically-shaped spacecraft, making them more sensitive to the thermal changes created by seasonal variations in the incident sun angle.

The WESTAR V spacecraft was 216 cm (86 in) in diameter and 659 cm (257 in) high when fully deployed in space. It weighed 1105 kg (2450 lb) following injection into elliptic transfer orbit. After its apogee motor fired, the on-station weight was 584 kg (1290 lb). On-orbit stationkeeping and attitude control was provided by four 22.2 newton thrusters, which operated with 142 kg of monopropellant hydrazine carried in four titanium tanks. Telemetry, tracking, and command functions were performed at 6/4 GHz.

Project Objectives — WESTAR V was the second in a series of second-generation large, 24-transponder communications satellites developed for the Space Communications Company. The satellite was built by Hughes Aircraft Company and was a spin stabilized (HS 376) design. Hughes had contracted to build three for Satellite Business Systems, five for Telesat Canada (Anik C and D), two for Indonesia (Palapa-B), and four for Australia.

Spacecraft Payload — Unlike earlier WESTAR designs, the entire WESTAR V transponder was despun. This permitted use of a more complicated antenna feed and reduced power loss. In addition, each of the 24 communication channels in the satellite's transponder used a single 7.5 watt traveling wave tube amplifier, in contrast to the 5 watt tubes used in the first three WESTARs. The transponder's traveling wave tubes (TWTs) were scaled versions of higher power Anik D TWTs; they were exactly the same but have a reoptimized helix for lower power. The change to higher power tubes

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was made possible by the greater battery capacity of the larger WESTAR V spacecraft. With the antenna gain developed by the single, large, shaped beam reflector, a single strength of at least 34 dBW was generated throughout the continental United States — a 1 dB improvement over earlier WESTARs. The satellite also provided upgraded performance for its noncontinental coverage areas. Redundant receivers in the transponder employed solid-state FET microwave integrated circuit techniques.

The satellite was the focus a single gain-weighted shaped beam over the continental United States with the higher gain over the eastern portion of the U.S. The weighted beam was created by a 183 cm (72 in.) reflector with two reflecting surfaces. The front horizontal grid reflector was transparent to vertically polarized signals, which were reflected from the rear reflector. Superimposition of reflectors in a single aperture allowed two reflectors to share structural support and use the largest diameter possible. The two reflectors were offset from each other at the bottom, allowing a corresponding offset of the focal planes. This offset permitted separate feed arrays for transmit and receive which do not physically interfere with each other.

Project Results — Delta 162, the WESTAR V mission, was launched from the Eastern Space and Missile Center, Pad 17A, on June 9, 1982. Both the launch vehicle and the PAM-D stages met all performance goals and achieved the following set of orbit parameters:

WESTAR V Vehicle Transfer Orbits

	Second Stage		PAM Stage	
	Predicted	Actual	Predicted	Actual
Apogee (km)	281.201	280.507	36567.1	35,942.8
Perigee (km)	−618.262	−617.961*	166.396	185.1
Inclination (deg)	29.561	29.563	27.501	26.989

* Planned Impact

NASA Headquarters

Stanley I. Weiss	Associate Administrator for Space Transportation Operations
Joseph B. Mahon	Director, Expendable Launch Vehicle Program
Peter Eaton	Manager, Delta
Robert E. Smylie	Associate Administrator for Space Tracking and Data Systems

Goddard Space Flight Center

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David W. Grimes	Delta Project Manager
William A. Russell, Jr.	Deputy Delta Project Manager Technical
John D. Kraft	Manager, Delta Mission Analysis and Integration
Richard H. Sclafford	WESTAR V Mission Integration Manager

Ray Mazur	Mission Support
Robert Seiders	Mission Operations and Network Support Manager

Kennedy Space Center

Thomas S. Walton	Director, Cargo Operation
Charles D. Gay	Director, Expendable Vehicles Operations
D.C. Sheppard	Chief, Automated Payloads Division
Wayne L. McCall	Chief, Delta Operations Division
Barry Olton	Space Coordinator

Westar V leaves launch complex 17 on June 8, 1982.

STS-4

Project Objectives — Program overview, launch vehicle, spacecraft, description, see STS-1.

The flight crew for STS-4 was Commander Thomas K. (Ken) Mattingly II, 46, and Pilot Henry W. Hartsfield, 48.

Each successive flight in the series of four orbital test flights with orbiter Columbia was aimed at further verifying the Shuttle system's capability to do the job for which it was signed — haul heavy payloads into and out of Earth orbit with a reusable vehicle. STS-4 was the fourth of the planned four test flights in which flight worthiness of the Space Transportation System is demonstrated in a building-block scheme. Prime among the flight worthiness objectives was the operational compatibility of orbiter and its main tank and booster, and ground support facilities.

Among the varied tests of orbiter systems was the orbiter's thermal response tests of passive thermal control for 20 hours (orbiter long axis perpendicular to the Sun line); 80 hours tail to Sun; 40 hours bottom to Sun and 10 hours payload bay toward Earth.

In addition to Developmental Flight Instrumentation in the payload bay, STS-4 carried the first operational Getaway Special canister containing nine experiments from Utah State University; and Department of Defense payload DOD 82-1.

Testing Columbia's Canadian-built robot arm, or payload deployment and retrieval system, continued on STS-4. The arm was to lift the Induced Environment Contamination Monitor from the payload bay rack two separate times for measuring space environment around the orbiter and as an exercise in payload handling before nesting the sensor back in its holddown each time.

During launch and entry, orbiter aerodynamic performance was further measured to add to the knowledge gained in the first three orbital test flights.

During entry, a series of aerodynamic response tests were run in various speed regimes from hypersonic down through subsonic to evaluate orbiter stability and control system effectiveness.

Aerodynamic stick imputs and programmed test imputs activated the reaction control system jets and cycled the aerosurface controls in combination and singly to induce attitude oscillations.

Similar tests were run at subsonic speeds during the 1977 approach and landing test flights with orbiter Enterprise and on the previous three orbiter test flights.

Shuttle spacesuits, or extravehicular mobility units, were stowed in the airlock for a contingency spacewalk to close balky payload bay doors.

Spacecraft Payload — The first experiment by a commercial firm was carried on STS-4. This was an engineering test of the Continuous Flow Electrophoresis System. Unlike other electrophoresis equipment, it processes materials in a continuous stream. It was designed by McDonnell Douglas Astronautics Co., St. Louis, Missouri, which was conducting the experiment in collaboration with scientists of the Ortho-Pharmaceutical Division of Johnson and Johnson Co. The experiment was flown as part of a joint endeavor agreement in which NASA and industry become partners in promoting development of advanced commercial products in space. The companies agreed in advance to make the products derived from such experiments available to the public at reasonable cost.

Electrophoresis is a technique used to separate biological materials in a fluid according to their electrical charges as they pass through an electrical field. The process is used to produce many pharmaceuticals. On Earth, gravity-induced phenomena in the solution, such as settling and convection, limit the output and purity of materials produced by electrophoresis. In the near zero gravity of space, such limitations are largely removed. On June 30, Mattingly and Hartsfield reported that the materials used had been successfully separated in the Continuous Flow Electrophoresis System, supporting the potential use of this device in space to produce more, better and lower cost pharmaceuticals.

In another experiment with many medical and scientific applications, STS-4 carried the Monodisperse Latex Reactor which performed successfully on STS-3. Some of the STS-3 experiments were used as "seed" items to test whether larger monodispersed (identically sized) microspheres could be produced in space. The size to which such spheres can be developed on Earth is limited because of Earth's gravity. Production in space may result in microspheres that will be widely used in calibrating instruments such as electron microscopes and in carrying precise amounts of drugs and isotopes directly to diseased or cancerous tissues.

Mattingly and Hartsfield participated in two medical experiments, both of which were winning entries of the Shuttle Student Involvement Project of NASA and the National Science Teachers Association. One experiment was by Amy Kusske of Wilson High School, Long Beach, California, and the other by Karla Hauersperger of East Mecklenberg High School, Charlotte, North Carolina. Mattingly's and Hartsfield's blood and urine were sampled before and after their flight. They recorded their food intake and exercise periods. Miss Kusske wanted to determine whether proper distribution of cholesterol in the body in microgravity requires strenuous exercise. Miss Hauersperger sought to know whether microgravity reduces chromium levels. A chromium deficiency decreases effectiveness of insulin and can produce diabetes-like symptoms. The biomedical laboratories at NASA's Johnson Space Center analyzed the blood and urine samples for both experimenters.

STS-4 also carried the first Getaway Special, the popular name for the Space Transportation System's Small Self-Contained Payload Program. Customers anywhere in the world can purchase a Getaway Special for as little as $3,000 for scientific and technological experiments.

The STS-4 Getaway Special was purchased by Gilbert Moore of North Ogden, Utah, for $10,000 and donated to Utah State University. Its nine experiments by university students covered such fields of microgravity as growth of fruitflies, brine shrimp, duckweed, and algae; testing the thermal conductivity of an oil and water mixture in a near-weightless environment; soldering; alloying; surface tension; and curing of composite materials.

A defective circuit prevented electrical power from reaching the Getaway Special. After several attempts to turn on the experiment failed, Mattingly and Hartsfield followed a technique devised by NASA engineers and described as comparable to "hot wiring" an automobile to start it without an ignition key. Anxious University of Utah students learned on June 29 that their experiment had been turned on and exultingly praised the crew, paraphrasing Apollo 11 astronaut Neil Armstrong as he first set foot on the Moon. They radioed: "One small switch for NASA; a giant turn-on for us."

The crew employed the huge manipulator arm in the cargo bay twice to lift and swing the Induced Environment Contamination Monitor (IECM) around the payload area to get information about particles, moisture, and gases in the bay that could affect experiments. The bay was facing the Sun during these experiments to gain maximum release of orbiter contaminants. When they first tried to use the arm on June 29, the crew saw a glowing trouble light, indicating that the snare-like end effector of the robot arm would not grasp the IECM. This turned out to be a false alarm.

Department of Defense Payload, DOD 82-1, shared the payload bay.

Project Results — Launched from Kennedy Space Center, Florida, at 11:00 a.m. EDT, June 27, 1982. After a successful flight of 169 hours, 10 minutes, the Columbia landed at Edwards Air Force Base, California, at 12:09 p.m. EDT, July 4, 1982.

STS-4 was the smoothest and most successful of the orbiter test flights. The flawless countdown was achieved despite pre-launch torrential rains and a hail storm which pitted and drenched Columbia's skin tiles. Before launch, technicians applied hardening chemicals to smooth and strengthen the tiles.

The two reusable solid rocket boosters were lost when they plunged into the Atlantic Ocean and sank in about 3100 feet of water. This was the first time the booster rockets were not recovered. "The only conclusion we can draw," George B. Harday, Solid Rocket Booster Manager said, "is that the main parachutes failed to function."

The test program for the mission exposed parts of Columbia for prolonged periods to extremes of heat and cold. Originally planned exposures called for tail to Sun for 66 hours; bottom to Sun for 33 hours; and payload bay to Sun exposure for 5 hours.

These periods were altered because hail had damaged numerous tiles, allowing them to absorb water. Engineers were concerned that the water-soaked tiles might freeze and be further damaged. Consequently they oriented the orbiter allowing its rain-soaked underside to face the Sun — to dry the tiles by vaporizing the water. Temperature readings from instrumented tiles were used to verify that the affected tiles had dried completely.

While keeping the underside facing the Sun, Mattingly and Hartsfield continued their experiments and opened and closed the payload bay doors on the cold side of Columbia. One door failed to close properly during this procedure.

When a similar problem occurred during STS-3, it was corrected by rolling the orbiter to heat it evenly. By repeating this maneuver, Mattingly and Hartsfield were able to open and close the payload bay doors easily. This reassured the crew and engineers on Earth that structural warping responsible for the problem was a temporary difficulty and could be solved with relatively simple procedures.
At 3:02 a.m. EDT, July 3, 1982, the Columbia sped past the spent upper stage of a rocket used to orbit a Soviet satellite in 1975. Although they came within eight miles of each other, they were never in danger of collision.

Columbia's reentry into the atmosphere and its return to Earth were planned to be more rigorous than previous flights. This was done to generate more heat to test its thermal-resistant structure and protective tiles. The crew also tested Columbia's ability to stabilize itself after rapidly pitching its nose up and down.

Columbia landed for the first time on a concrete runway approximately 300 feet wide and 15,000 feet long. The previous three orbiter mission landings were on dry lakebeds.

Columbia's nearly flawless performance on its final test mission resulted in certification of the Space Transportation System (STS) as a fully operational carrier.

President Ronald Reagan compared the achievement with the "golden spike" that signaled the beginning of transcontinental railroading in an earlier era.

Major Participants

NASA Headquarters

Maj. General J. A. Abrahamson	Associate Administrator for Space Transportation Systems
L. Michael Weeks	Deputy Associate Administrator for Space Transportation Systems
Joe H. Engle	Deputy Associate Administrator for Space Flight
David R. Braunstein	Deputy Associate Administrator for Space Transportation Systems (Management)
Walter F. Dankoff	Director, Engine Programs
Edward P. Andrews	Director, Ground Systems and Flight Test
Frank Van Rensselear	Director, Upper Stages
Jerry J. Fitts	Director, Solid Rocket Booster and External Tank
Robert E. Smylie	Associate Administrator for Space Tracking and Data Systems

Johnson Space Center

Glynn S. Lunney	Manager, Space Shuttle Program
Aaron Cohen	Manager, Space Shuttle Orbiter Project Office
George W. S. Abbey	Director of Flight Operations
Robert O. Piland	Director of Engineering and Development
Lynwood C. Dunseith	Director of Data Systems and Analysis

Kennedy Space Center

Dr. Robert H. Gray	Manager, Shuttle Projects Office
John J. Neilon	Manager, Cargo Projects
George F. Page	Director, Shuttle Operations
Alfred D. O'Hara	Director, STS Processing
Thomas S. Walton	Manager, Cargo Operations

Marshall Space Flight Center

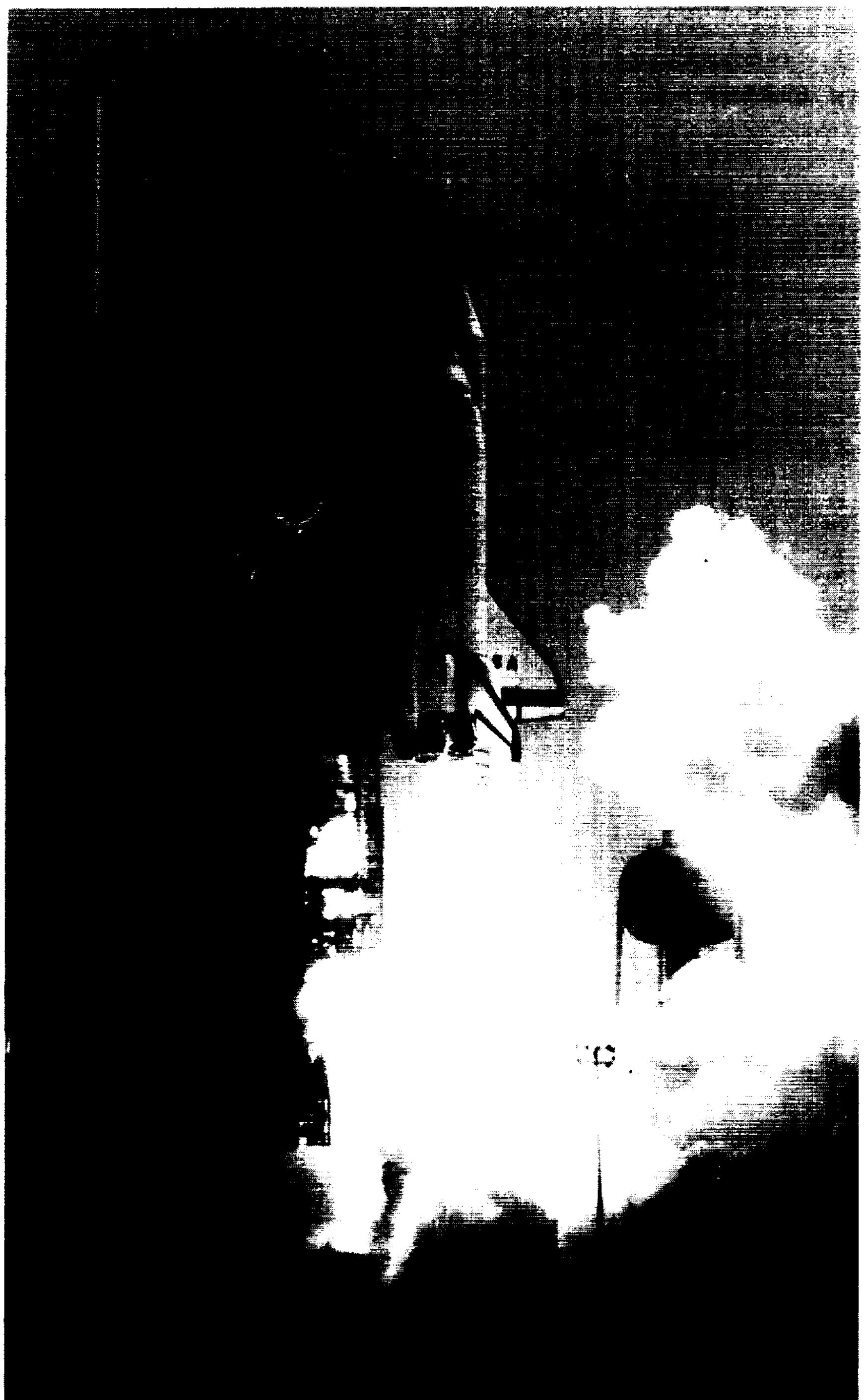
Robert E. Lindstrom	Manager, MSFC Shuttle Project Office
James E. Kingsbury	Director, Science and Engineering Directorate
James B. Odom	Manager, External Tank Project
George B. Hardy	Manager, Solid Rocket Booster Project
James M. Sisson	Manager, Engineering and Major Test Management Office
Judson A. Lovingood	Acting Manager, Space Shuttle Main Engine Project

Dryden Flight Research Facility

John A. Manke	Facility Manager
Gary Layton	Shuttle Project Manager

Goddard Space Flight Center

Richard S. Sade	Director of Networks Directorate Space Tracking and Data Network
Walter LaFleur	Deputy Director of Networks Directorate (STDN)
William B. Dickinson	Division Chief, NASA Communications Network
Donald D. Wilson	Assistant Chief, NASA Communications Network
Daniel Spintman	Chief, Network Operations Division
James M. Stevens	Shuttle Network Support Manager



STS-4 — Both of Columbia's attached solid rocket boosters fire to lift the reusable space vehicle off Launch Pad 39A and on her way toward a 241 kilometer (130 nautical mile) circular orbit on June 27, 1982.

Key Spacecraft Personnel

Monodisperse Latex Reactor

PI	John W. Vanderhoff	Lehigh University
OI	Fortunato J. Micale	Lehigh University
OI	Mohamed S. El-Aasser	Lehigh University
OI	Dale Kornfeld	Marshall Space Flight Center

Nighttime/Daytime Opheal Survey of Lightning

PI	Otha H. Vaughan, Jr.	Marshall Space Flight Center
and	Marx Brook	New Mexico Institute of Living and Technology

Continuous Flow Electrophoresis System
Ortho-pharmaceutical Division of Propulsion and Johnson in collaboration with McDonnell Douglas

Getaway Special
PI Gilbert Moore Utah State University

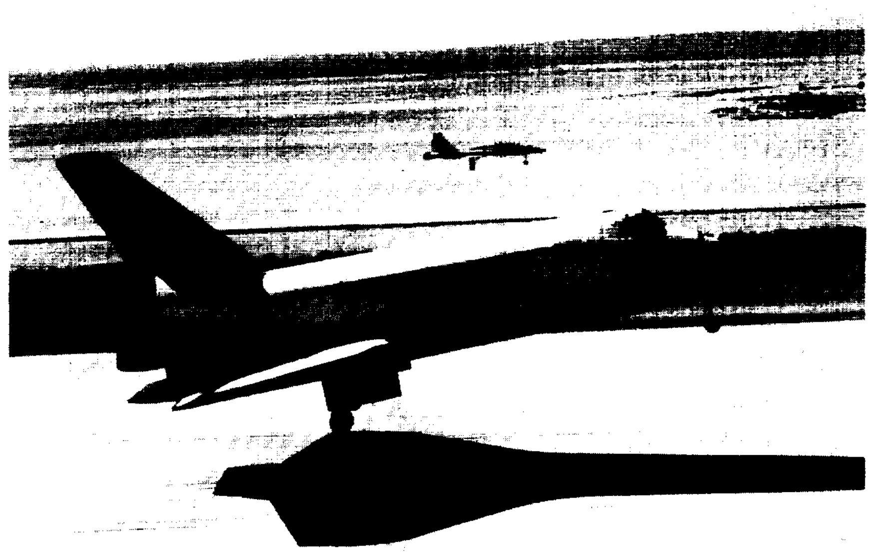
Aerodynamic Coefficient Identification Package
PI D. B. Howes Johnson Space Center

Implanted Imagery of Shuttle
PI W. C. Davy Ames Research Center

Tile Gap Heating Effects Experiment
PI W. Pitts Ames Research Center

Catalyts Surface Effects Experiment
PI D. Stewart Ames Research Center

Dynamic, Acoustic and Thermal Environment Experiment
PI W. Bangs Goddard Space Flight Center



STS-4 begins its touchdown — the first on a concrete runway — at Edwards Air Force Base, California. July 4, 1982

LANDSAT D

Launch Vehicle — The Landsat D spacecraft was the first mission launched by the new Delta 3920, which was a thrust-augmented NASA Delta 3910 launch vehicle.

The Delta 3920 was 35.5 m (116 ft) long, including the spacecraft shroud. Liftoff weight is 189,087 kg (415,990 lb) and liftoff thrust was 2,058,245 newtons (547,504 lb) including the startup thrust of six of the nine strap-on solid rocket motors (the remaining three motors were ignited at liftoff plus 60 seconds).

The first stage booster was an extended long-tank Thor powered by the Rocketdyne RS-27 engine. This engine used hydrazine (RP-1) fuel and liquid oxygen oxidizer. Pitch and yaw steering was provided by gimballing the main engine. Vernier engines provided roll control during powered flight and coast.

The Delta 3910 incorporated a new second stage consisting of large diameter propellant tanks coupled with the new Aerojet Liquid Rocket Company's AJ-10-118 improved transtage injector program (ITIP) engine. This stage was powered by a liquid propellant engine using nitrogen tetroxide (N_2O_4) as oxidizer and Aerozene 50 as fuel. Pitch and yaw steering during powered flight was provided by gimballing the engine. Roll steering during powered flight and coast was provided by a nitrogen gas thruster system.

Spacecraft Description — The main body of the spacecraft consisted of NASA's standard multimission modular spacecraft and the Landsat instrument module. The long dimension of the spacecraft body (roll axis) lies in the plane of the orbit. The yaw axis was oriented to the local vertical (parallel to the antenna mast). The pitch axis was normal to the orbit plane and parallel to the axis of rotation of the solar array.

Principle spacecraft measurements:

Weight	1941 kg (4273 lb)
Launch weight margin	127 kg (280 lb)
Orientation control	three axis momentum wheels
Power	at mission start = 990 watts
	at mission end = 814 watts

Project Objectives — The Landsat D program had the major objectives:

- To provide continuing Earth remote sensing information and to encourage continued national and international participation in land remote sensing programs;
- To assess the capabilities of the new thematic mapper sensing system and to exploit new areas of the infrared and visible light spectrum at higher resolution; and
- To establish a technical and operational proficiency which can be used to help define the characteristics necessary for potential future operational land remote sensing systems.

Because of the proven value of the Landsat series, which NASA had flown as experiments in remote sensing, the Landsat D was to become the first interim operational remote sensing satellite. It was to be turned over to NOAA with NOAA then being responsible for controlling the spacecraft, scheduling the use of the sensors, data processing, and distributing the data through the Department of Interior's Earth Resources Observation System (EROS) Data Center in Sioux Falls, SD. NASA would continue to be responsible for the data processing until January 1985.

Spacecraft Payload — Landsat D incorporated two highly sophisticated sensors: the flight proven multispectral scanner, one of the sensors on the Landsat 1, 2, and 3 spacecraft; and a new instrument expected to advance considerably the remote sensing capabilities of Earth resources satellites. The new sensor, the thematic mapper, was to provide data in seven spectral (light) bands with greatly improved spectral, spatial, and radiometric resolution.

The principal instruments were the thematic mapper, located at the transition adapter between the instrument module and the multimission modular bus, and the multispectral scanner which was located at the forward end of the instrument module. Each instrument used an ocsillating mirror to scan the Earth's surface in the cross-track direction (perpendicular to the spacecraft ground track). The motion of the spacecraft along the ground track provided the along-track scan.

The thematic mapper used a multistage passive radiator cooler for temperature control of the thermal band detectors. The cooler was on the opposite side from the Sun.

The mast mount for the TDRSS communications assembly extended about 4 m (13 ft) above the spacecraft body to provide a clear field-of-view to the relay satellite from horizon to horizon. An L-band antenna mounted on this mast provided a link with the global positioning system satellites.

The solar array, with its single axis of rotation drive mechanism, moved at orbital track rate to follow the sun. It incorporated a fixed bend in the mount to orient the solar collectors perpendicular to the Sun.

Project Results — Launched from the Western Space and Missile Center, Vandenberg Air Force Base, California, on July 16, 1982.

The Landsat D program was keyed to user requirements and reliable data products delivery.

Information from Landsat was produced from the multispectral scanner both as computer compatible (on tape) and in the form of imagery (photo product). Each Landsat scene covered an area of 185 by 185 km (115 by 115 mi).

The multispectral scanner was essentially the same as those used on previous Landsat spacecraft. It acquired data simultaneously from four bands of the visible and near-infrared portions of the light spectrum. False color composite photos could be produced by combining several bands of information through filters onto color film.

The resulting pictures produced a great deal of useful data in color. Vegetation appeared in various shades of red, depending on species, stage of growth, and health of the plants. Cities and highways appeared blue. Water came out in shades from white through blue to black, depending on the depth, sediment load, and other characteristics.

Data from the multispectral scanner was received at the NOAA ground station facility developed by NASA, located at the Goddard Space Flight Center, where it was processed into a format suitable for archiving. The data was then transmitted via communications satellite to the Department of Interior EROS Data Center for further processing into computer compatible tapes or pictures.

To provide service to Landsat customers, NOAA entered into an agreement with Interior to continue EROS Data Center Landsat data activities under NOAA management. The NOAA Landsat activity at the Center was the hub for customer services.

Information similar to that produced by the multispectral scanner but in much greater detail was to be produced by the thematic mapper.

The thematic mapper covered the same areas as the multispectral scanner but with finer resolution using seven bands of the spectrum. Data from the thematic mapper was processed by NASA and scenes placed in the public domain by forwarding to the EROS Data Center for sale to the public.

Landsat D was imaging the same 185-km (115-mi) swath of the Earth's surface every 16 days. During this 16-day cycle, the entire Earth, except for small areas around both poles could be imaged.

Image data will be transmitted in realtime at Ku band (wideband high bit rate) via the Tracking and Data Relay Satellite once it is launched in 1983. Once the Landsat D begins using the TDRSS, communication will be through the relay satellite ground station at White Sands, New Mexico. Thematic mapper data will be recorded at the ground station and then relayed to Goddard via communications satellite. Multispectral scanner data can be either recorded at the White Sands station and relayed to Goddard or relayed in real time to Goddard for processing.

Until the TDRSS becomes operational, the downlink communications mode for MSS data would be through the Landsat D direct access S band link. The S band also provides for compatibility with existing Landsat 1, 2, and 3 ground stations in foreign countries. Thematic mapper data transmit directly to the ground at X band before the TDRSS is operational. The X band can be used instead of or in addition to the Ku band TDRSS communications modes.

Spacecraft telemetry and command communications were through the S band system, either directly through the TDRSS (when available) or through the existing ground spacecraft tracking and data network (managed by Goddard).

U.S.-required foreign multispectral scanner data was acquired at four foreign receiving stations and sent to the United States. The four stations were in Sweden, Brazil, Japan and Australia. Data tapes acquired at those stations were processed at Goddard after receipt.

Ephemeris data, required for spacecraft control and for ground processing and image correction was computed by Goddard. Following the checkout of the system, ephemeris was available through the Landsat D directly, using the global positioning system receiver.

Major Participants

NASA Headquarters

Dr. Burton I. Edelson	Associate Administrator for Space Science and Applications
Dr. Stanley I. Weiss	Associate Administrator for Space Transportation Operations
Robert E. Smylie	Associate Administrator for Space Tracking and Data Systems
Jesse W. Moore	Director, Earth and Planetary Exploration Division
Dr. Geoffrey Briggs	Deputy Director, Science, Earth and Planetary Exploration Division
James C. Welch	Deputy Director, Technical, Earth and Planetary Exploration Division
Harry Mannheimer	Program Manager, Landsat D
Joseph B. Mahon	Director, Expendable Launch Vehicles Division
Peter Eaton	Program Manager, Delta

Goddard Space Flight Center

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William C. Keathley	Director, Flight Projects Directorate
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Frank L. Heddinger	Deputy Project Manager, (Resources), Landsat D
Dr. Vincent Salomonson	Project Scientist, Landsat D
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Joseph B. Schulman	Systems Manager, Landsat D
Joseph Arlauskas	Systems Manager, Instruments, Landsat D
Lottie E. Brown	Software Manager, Landsat D
Jerold Hahn	Ground Data Processing Systems Manager, Landsat D
William C. Webb	Mission Operations Manager, Landsat D
Richard A. Devlin	Spacecraft Manager, Landsat D
Oscar Weinstein	Instrument Systems Manager, Landsat D
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William A. Russell, Jr.	Deputy Delta Project Manager, Technical
J. Donald Kraft	Manager, Delta Mission Analysis and Integration
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Robert I. Seiders	Mission Operations and Network Support Manager
Ray Mazur	Mission Support

Kennedy Space Center

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Charles D. Gay	Director, Expendable Vehicles Operations Directorate
Wayne L. McCall	Chief, Delta Operations Division
Ray Kimlinger	Chief, Delta Western Operation Branch
Pat Murphy	Manager, STS Resident Office (VAFB)
C. R. Fuentes	Spacecraft Coordinator

National Oceanic and Atmospheric Administration (NOAA)

Dr. John V. Byrne	Administrator
Dr. Anthony J. Calio	Deputy Administrator
James W. Winchester	Associate Administrator

NOAA National Earth Satellite Service

Dr. John H. McElroy	Assistant Administrator for Satellites
Harold Yates	Acting Deputy Assistant Administrator for Satellites
E. Larry Heacock	Director, Office of Systems Development
Russell Koffler	Director, Officer of Data Services
Edward F. Conlan	Chief, Landsat Operations Division, Office of Data Service

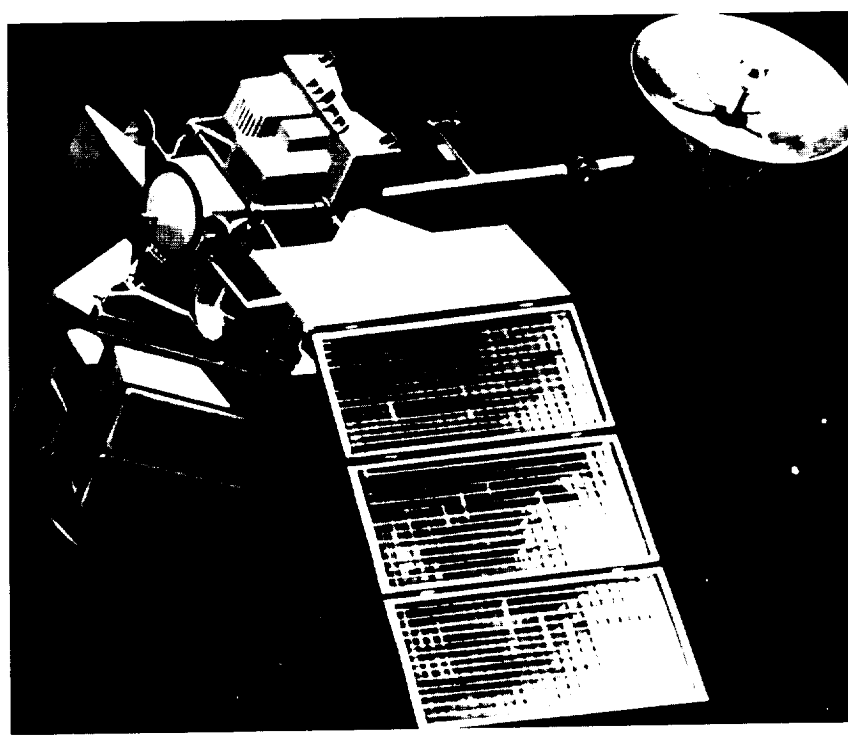
Contractors

General Electric Company Space Systems Division Valley Forge, PA	Landsat D Spacecraft Landsat D Ground System
Hughes Aircraft Company Los Angeles, CA	Thematic Mapper Multispectral Scanner
Fairchild Industries Fairchild Space & Electronics Germantown, MD	Multimission Modular Spacecraft

McDonnell Douglas Corp. McDonnell Douglas Astro. Co. Huntington Beach, CA	Delta 3920 Launch Vehicle Payload Assist Module (PAM) Payload Stage
Rockwell International Rocketdyne Division Canoga Park, CA	Delta First Stage Engine (RS-27)
Thiokol Corporation Huntsville, AL	Castor IV Strap-on Engines
Aerojet Liquid Rocket Sacramento, CA	AJ10-118K (ITIP) Second Stage Engine
General Motors Corporation Delco Division Santa Barbara, CA	Guidance Computer

Key Spacecraft Personnel

Experiment	Experiment Personnel
Multispectral Scanner	PI G. F. Banks NASA/GSFC
Global Positioning System	PI P. M. Feinberg NASA/GSFC
Thematic Mapper	PI O. Weinstein NASA/GSFC



Landsat D (artist's sketch) The satellite was launched July 16, 1982.

TELESAT G
ANIK - D

Launch Vehicle — Delta 3920 with Payload Assist Module (PAM). This was the second launch of the NASA Delta 3920 launch vehicle, and the first launch of this version from the Eastern Space and Missile Center. (The first launch was Landsat 4 from the Western Space and Missile Center on July 16, 1982.)

The Delta Model 3920 straight-eight configured launch vehicle consisted of an extended long tank Thor first stage with an RS-27 engine augmented with nine Castor IV solid rocket motors, a new second stage powered by an Aerojet AJ10-118K engine, and a 2.4 m (96-in.) diameter spacecraft fairing.

After separation of the payload third stage (PAM) and spacecraft from the second stage, NASA/Delta responsibilities were concluded. Payload Assist Module ignition occurred at 1,297 seconds and was to burn for 86 seconds, placing the payload into geostationary transfer orbit.

Spacecraft Description — The spacecraft was a synchronous altitude geostationary satellite designed to operate over a 10-year life span.

The two main elements of the spacecraft were the spinning rotor, comprising 70 percent of the on-station vehicle weight, and the despun Earth-oriented platform containing the communication repeater and its antenna. The overall spacecraft length, at launch, was 2.8 meters (7.8 feet); its maximum diameter 2.17 m (7.1 feet). After antenna deployment and extension of one solar panel cylinder, the overall spacecraft length was 6.7 m (22 feet).

Program Objective — This was Canada's 10th satellite and the fifth spacecraft in a series of domestic commercial communications satellites owned and operated by Telesat Canada. The spacecraft was to be placed into a geosynchronous orbit to provide communications coverage over Canada, the second largest nation in area in the world.

The spacecraft was to be positioned at 104 degrees west longitude within 30 days after launch and used by Telesat as an in-orbit replacement/backup for the three aging Anik-A (1972, 1973, 1975) and Anik-B (1978) satellites.

Spacecraft Payload — Telesat carried a 24-channel communications payload. Its payload was integrated and tested by Spar Aerospace of Canada.

Major Participants

NASA Headquarters

Lt. Gen. J.A. Abrahamson	Associate Administrator for Space Flight
Joseph B. Mahon	Director, Expendable Launch Vehicle Program
Peter Eaton	Program Manager, Delta
R. E. Smylie	Associate Administrator for Space Tracking and Data Systems

Goddard Space Flight Center

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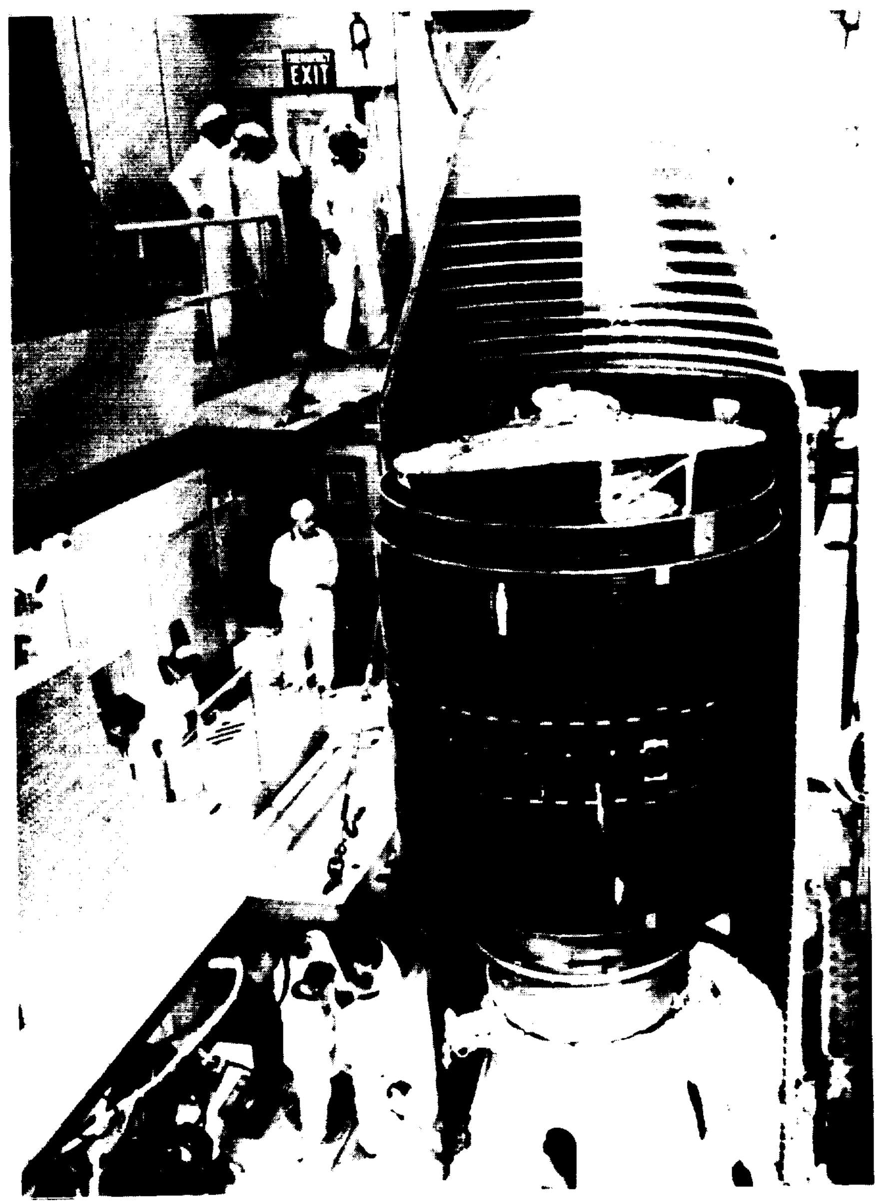
David W. Grimes	Delta Project Manager
William A. Russell, Jr.	Deputy Delta Project Manager Technical
John D. Kraft	Manager, Delta Mission Analysis and Intergration
Warner H. Hord	Telesat Mission Integration Manager
Robert I. Seiders	Mission Operations and Network Support Manager
Ray Mazur	Mission Support



Telesat G/Anik D-1 being prepared for launch aboard a Delta booster. August 26, 1982.

Kenndey Space Center

Thomas S. Walton	Director, Cargo Operations
Charles D. Gay	Director, Expendable Vehicles Operations
Wayne L. McCall	Chief, Delta Operations
Jim Weir	Acting Chief, Automated Payloads Division
Gayle Hager	Spacecraft Coordinator

TELESAT Canada

Eloon Thompson	President
William Zatychec	Director, Satellite Systems Division
Dave Griffiths	Manager, Launch Services
John Korda	Space Manager, Anik-D
Ray Miles	Range Coordinator, Anik-D

INTELSAT V-E

Launch Vehicle — The Intelsat V-E was launched into a transfer orbit by an Atlas-Centaur launch vehicle. The rocket combination, standing approximately 41 meters(133 ft) high, consisted of an Atlas SLV-3D booster and Centaur D-1A second stage.

The Atlas booster developed 1913 kilonewtons (430,000 lb) of thrust at lift-off using two 828,088 newton (184,841 lb) thrust booster engines, one 267,000 newton (60,000 lb) thrust sustainer engine, and two vernier engines developing 3006 newton (676 lb) thrust each. Its propellants were RP-1 (a kerosene type fuel) and liquid oxygen (LOX).

Launch Vehicle Characteristics

Liftoff weight including Spacecraft	147,871 kg (326,000 lb)
Liftoff height	40.5 meters (133 ft)
Launch Azimuth	97.6 degrees

	Atlas Booster	**Centaur Stage**
Weight	128,934 kg (284,248 lb)	17,676 kg (38,970 lb)
Height	21.3 meters (70 ft)	18.6 meters (61 ft) (with payload fairing)
Thrust	1931 kilonewtons (431,000 lb)(sea level)	1334.4 kilonewtons (30,000 lb) (vacuum)

Spacecraft Description — Aluminum main body structure with graphite epoxy antenna tower and catalytical and electro-thermal hydrazine thrusters of modular construction. Its three-axis body stabilized with Sun and Earth sensors and momentum wheels. It carried wing-like Sun-oriented solar array panels which produced a total of 1.241 watts of electrical power.

Dimensions —

- Solar Array (end to end) : 15.6 meters (51.1 feet)
- Main Body "Box" : 1.66 × 2.01 × 1.77 meters (5.4 × 6.6 × 5.8 feet)
- Height : 6.4 meters (21 feet)
- Width (fully deployed) : 6.8 meters (22.25 feet)
- Weight (at launch, without MCS) : 1,928 kilos (4,251 pounds)

Project Objectives — Intelsat V-E weighted 1,972.3 kilograms (4,348 pounds) at launch and almost doubled the communications capability of earlier satellites in the Intelsat series — 12,000 voice circuits and two color television channels. The flight was also to carry for the first time a Maritime Communications Services (MCS) package for the Maritime Satellite Organization (INMARSAT) to provide ship/shore/ship communications.

Spacecraft Payload — The spacecraft's communications subsystem received and amplified signals from Earth, routes the signals between antenna beams, and retransmits the signals back to Earth. The equipment involved included 15 receivers, 43 traveling wave tube amplifiers, and more than 140 microwave switches. The repeater provided 27 separate combinations of coverage areas and frequency bands. Solid state receivers, graphite epoxy filters, and contiguous channel output multiplexers were among the technical innovations introduced in this subsystem.

A team of international manufacturing concerns developed and producded major spacecraft payload components. This includes:

Aerospatiale (France) initiated the structural design that forms the main member of the spacecraft modular design construction. It supplied the main body structure thermal analysis and control.

GEC-Marconi (United Kingdom) produced the 11 GHz beacon transmitters used for Earth station antenna tracking.

Messerschmitt-Bolkow-Blohm (Federal Republic of Germany) designed and produced the satellite's control subsystem and the solar array.

Mitsubishi Electric Corporation (Japan) was responsible for both the 6 GHz and the 4 GHz Earth coverage antennas. It also manufactured the power control electronics, the telemetry, and command digital units.

Selenia (Italy) designed and built the six telemetry, command, and ranging antennas, two 11 GHz beacon antennas and two 14/11 GHz spot beam antennas. It also built the command receiver and telemetry transmitter which combine to form a ranging transponder for determination of the spacecraft position in transfer orbit.

Thomson-CSF (France) built the 10 w, 11 GHz traveling wave tubes of which there were 10 per spacecraft.

Project Results — Successfully launched from Eastern Space and Missile Center on September 28, 1982. The spacecraft was injected into an Earth-synchronous orbit and positioned over the Indian Ocean as the prime Intelsat satellite to provide communications services between Europe, the Middle East, and the Far East.

Major Participants

Intelsat

Andrea Caruso	Deputy Director General, Administration
Francis Latapie	Acting Deputy Director General, Administration
Allan M. McCaskill	Manager, Launch Vehicle Program Office

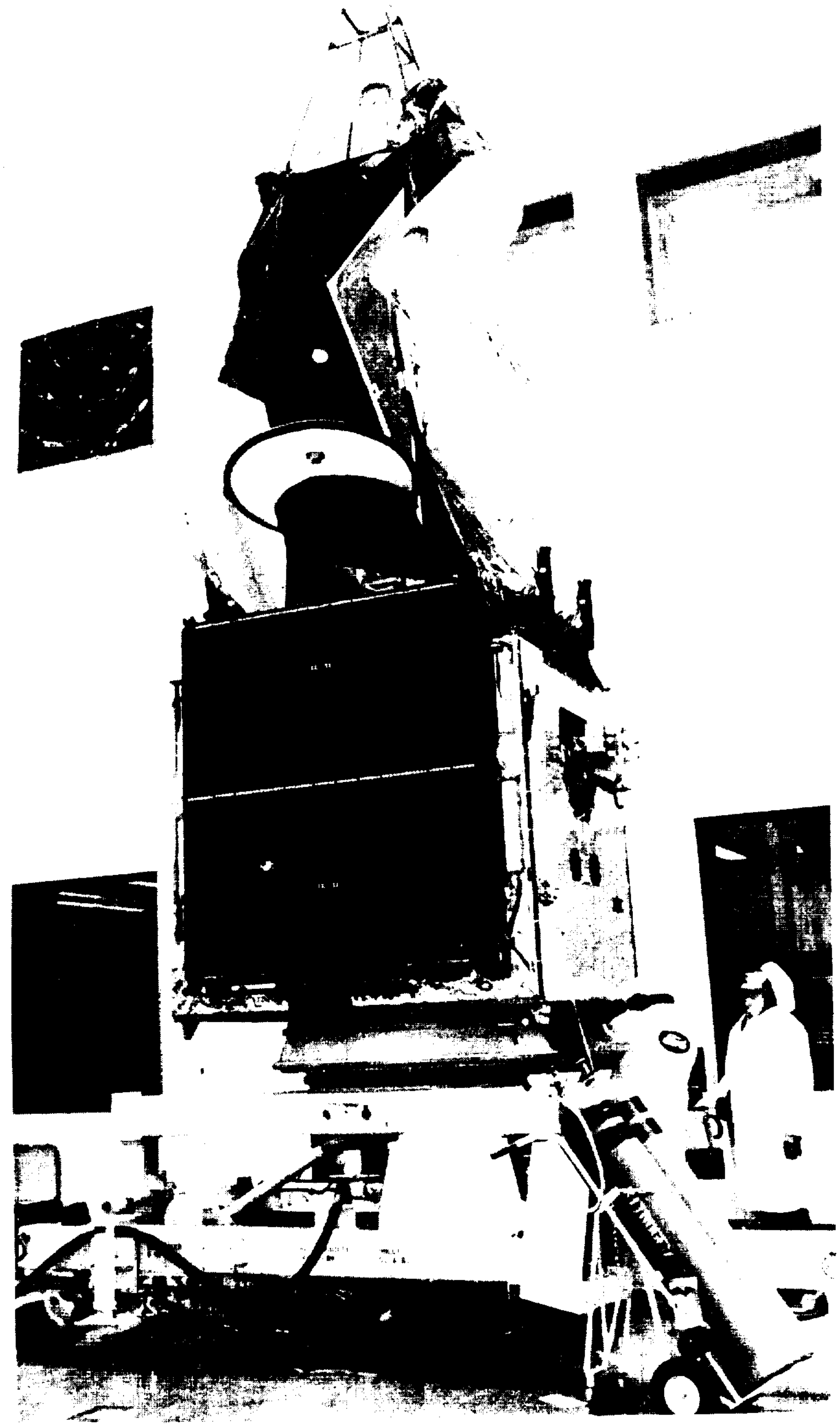
NASA Headquarters

Lt. Gen. J. A. Abrahamson	Associate Administrator for Space Flight
J. B. Mahon	Acting Director, Special Programs
F. R. Schmidt	Atlas Centaur Manager

Lewis Research Center

James E. Patterson	Director, Launch Vehicles
Richard E. Orzechowski	Mission Project Engineer

On September 28, 1982, Intelsat V-E was launched. Here technicians make final checks on the 4300-pound satellite. It was the first in a new series of communications satellites for the International Telecommunications Satellite Corporation.



Kennedy Space Center

Charles D. Gay	Director, Expendable Vehicles Operations
James L. Womack	Chief, Centaur Operations Division
Donald G. Sheppard	Chief, Automated Payloads Division
Larry F. Kruse	Intelsat Spacecraft Coordinator

Prime Contractors

Ford Aerospace & Communications Corp. Palo Alto, CA	Intelsat V Spacecraft
General Dynamics/Convair San Diego, CA	Atlas Centaur Vehicle
Honeywell, Aerospace Div. St. Petersburg, FL	Centaur Guidance Inertial Measurement Group
Pratt & Whitney West Palm Beach, FL	Centaur RL-10 Engines
Teledyne Systems Co. Northridge, CA	Digital Computer Unit/PCM Telemetry

RCA-E (SATCOM V)

Launch Vehicle — This was the first launch of a Delta 3924 vehicle, although two Delta 3920 configurations were previously launched. This three-stage Delta vehicle consisted of: an extended long tank first stage with rocketdyne RS-27 engine and nine Castor IV strap-on solid motors for the first stage; the new improved Aerojet AJ10-118K second stage; a Thiokol TE-364-4 third-stage engine. The entire vehicle was 2.4 meters (8 feet) in diameter (excluding the strap-on solid motors) and 36 m (116 feet) high.

Spacecraft description — Satcom V weighed 1,112 kilograms (2,452 pounds) on the ground and had an in-orbit mass of 590 kilograms (1,300 pounds), after burning its apogee motor solid propellant. Its main body measured 142 × 163 × 175 centimeters (56 × 64 × 69 inches), and it was 15.8 meters (51.8 feet) wide with its solar panels extended. These produced up to 1,450 watts of power and would still produce about 1,100 watts after ten years of service, the expected life of the satellite. An internal spinning momentum wheel provided stability, and a magnetic torqueing technique (backed up by the small rocket thrusters) kept the antennas pointed at the Earth as the satellite circled around it. The two sets of three solar panels revolved about their long axes to keep their solar cell surfaces constantly toward the Sun for maximum power generation. Three nickle-cadmium batteries supply power when the satellite must operate in the Earth's shadow which was up to 72 minutes a day for several weeks twice each year.

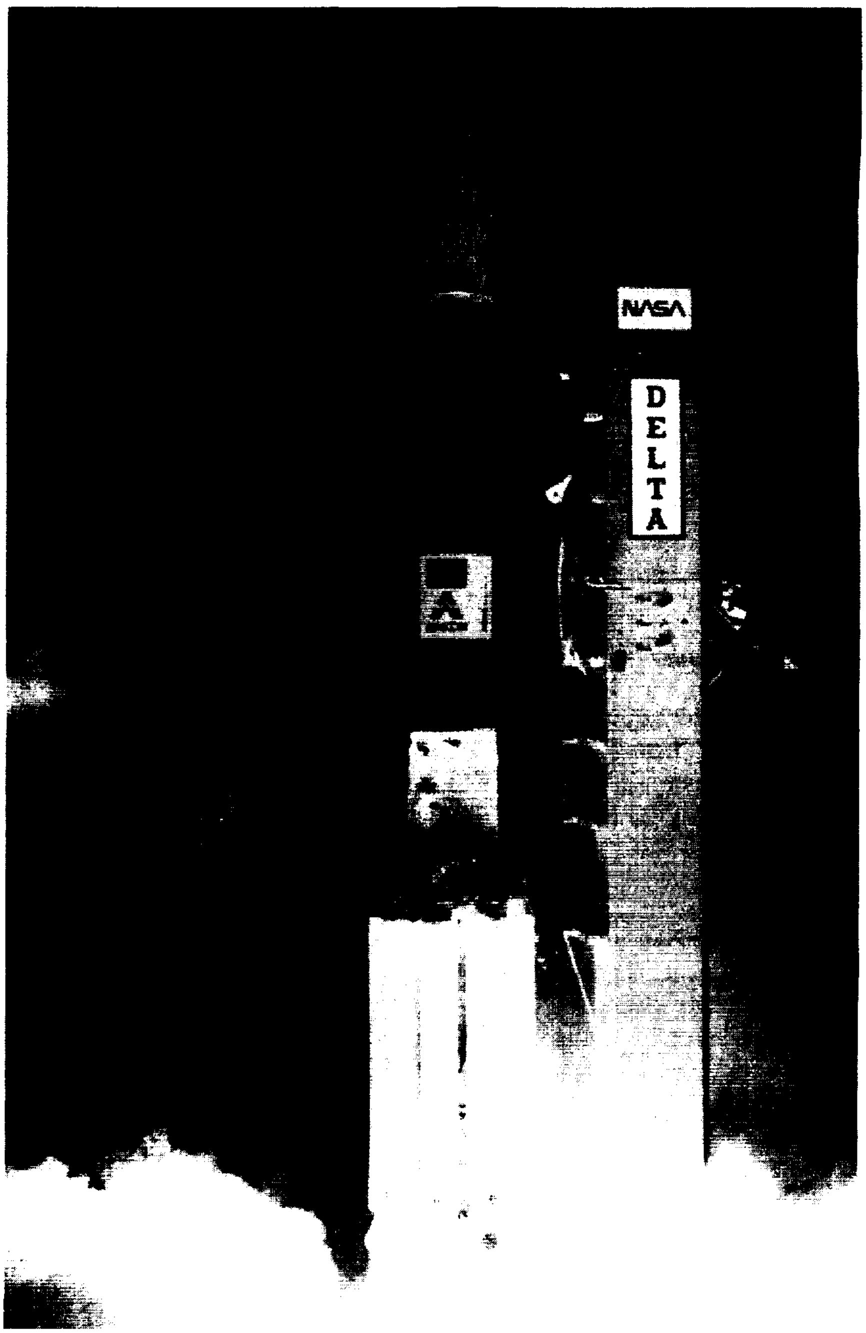
Project Objectives — The 24-channel satellite provided telecommunications and video programming services within Alaska and between Alaska and the rest of the United States.

Satcom V joined four other RCA satellites, Satcoms I, II, III-R, and IV in orbit. The satellites provided coverage for all 50 states and Puerto Rico with television, voice channels, and high-speed data transmissions. There were more than 4,000 Earth stations with direct access to these spacecraft.

Spacecraft Payload — Satcom V was a "second generation" spacecraft, called the "advanced Satcom." It was the first all solid-state commercial communications satellite. It had 28 individual 8.5 watt RF solid-state power amplifiers, one for each of the 24 transponders (channels), and four spares. They were powered by four electronic power conditioners, each of which contained two dc-to-dc power converters. Six of these converters could supply the 24 operating transponders, leaving two spares. Earlier RCA Satcoms used traveling wave tube amplifiers, the standard throughout the industry. The advantages of the solid state amplifiers were higher reliability, much simpler power supply requirements, and improved performance characteristics.

Each of the 24 transponders could relay two color television signals, providing the right ground support equipment is available, double the capacity of prior RCA Satcoms. When used with a device on the ground called a compandor — which compressed the dynamic range of a voice for transmission and then expands it again after reception — a single transponder could carry about 1,400 two-way telephone conversations. Each channel had a bandwidth of 36 MHz, plus separation space between bands to prevent crosstalk. Communication satellites were limited to a total bandwidth of 500 MHz. By polarizing the signals from 12 transponders horizontally and the other twelve vertically, RCA Satcom channels could overlap on the same frequency without interferring with each other, and so doubled a satellite's transmitting capacity.

Project Results — Launched from the Eastern Space and Missile Center on October 28, 1982. Successfully placed into Earth-synchronous orbit, positioning the spacecraft at 143 degrees west longitude above the Equator, thus Satcom V could reach all of Alaska and the contiguous 48 states, with a separate spot beam for Hawaii.



RCA-E/Satcom V at lift-off. October 28, 1982.

Major Participants

NASA Headquarters

Lt. Gen. James A. Abrahamson	Associate Administrator for Space Flight
Joseph B. Mahon	Director, Expendable Launch Vehicle Program
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John D. Kraft	Manager, Delta Mission Analysis and Integration
Richard H. Sclafford	RCA Satcom V Mission Integration Manager
Robert Seiders	Network Support Manager
Ralph Banning	Mission Support

Kennedy Space Center

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Thomas S. Walton	Director, Cargo Operations
Charles D. Gay	Director, Expendable Vehicles Operations
D. C. Sheppard	Chief, Automated Payloads Division
Wayne L. McCall	Chief, Delta Operations Division
Barry Olton	Spacecraft Coordinator

RCA American Communications, Inc.

Andrew Inglis	President
John Christopher	Vice President of Technical Operations
Peter Plush	Manager, Major Programs and Technical Operations Services
Joseph Schwarze	Manager, Space Systems
William Palme	Manager, Major Programs Launch Vehicle Integration
Joseph Elko	Manager, Spacecraft Engineering

Contractors

RCA American RCA Astro Electronics Div. Princeton, NJ	Spacecraft Management Development/Production
McDonnell Douglas Astronautics Company Huntington Beach, CA	Delta Launch Vehicle
Rocketdyne Division Rockwell International Canoga Park; CA	First Stage Engine (RS-27)
Thiokol Corp. Huntsville, AL	Castor IV Strap-on Solid Fuel Motors
TRW Redondo Beach, CA	TR-201 Second Stage Engine

Major Subcontractors

SPAR Aerospace Division STE-Anne-de-Bellevue Quebec, Canada	Antenna Input and Output
Charles Stark Draper Labs Cambridge, MA	Momentum Wheel Assembly
Lockheed Space Systems Division Sunnyvale, CA	Earth Sensor Assembly and Horizon Sensor Assembly
Thiokol Corp. Elkton, MD	Apogee Kick Motor (Star 30) in Spacecraft
Hughes Aircraft Co. Electro-Dynamics Division Torrance, CA	Traveling Wave Tube Amplifiers
Rocket Research Redmond, WA	Reaction Engine Assembly
Cubic Corp. Defense Systems Division San Diego, CA	Beacon Transmitter and Command Receiver
Parsons of California Stockton, CA	Structure and Solar Panels
Adcole Corp. Waltham, MA	Sun Sensor Assembly
Northrop Corp. Norwood, MA	Rate Measuring Assembly

STS-5/ANIK C-3 (or Telesat 5)/SBS-3

Project Objectives — Program overview, launch vehicle, spacecraft description, see STS-1.

The fifth flight of the Space Shuttle marked the first operational use of the Nation's Space Transportation System. Spaceship Columbia's first operational job carried two commercial communications satellites — Satellite Business System's SBS-3 and Telesat Canada's Anik CO3 (also known as Telesat) into orbit.

Significant "firsts" for Columbia on STS-5 included:

- First Space Shuttle flight to carry and deploy commercial satellites into space.
- First flight with a crew of four astronauts.
- First flight of Mission Specialists aboard the Space Shuttle.

The first planned "space walk" to demonstrate the Extravehicular Mobility Unit was cancelled because of a faulty ventilation fan motor in one space suit back pack and a balky pressure regulator in the other.

Spacecraft Payload — The principal cargo carried on STS-5 consisted of two commercial communications satellites, SBS-3 and Anik C-3. Other items carried in the cargo bay included a Getaway Special (GAS) canister and the Development Flight Instrumentation (DFI) package. Experiments in the orbiter's mid-desk included three Shuttle Student Involvement Project experiments. The Remote Manipulator Arm had been removed for STS-5.

The STS-5 marked the first use of the Shuttle Payload Assist Module, PAM-D, and a new ejection system. A modified version of the Payload Assist Module had been used as the third stage of NASA's Delta rocket to propel a variety of satellites to geosynchronous orbit.

Satellite Business Systems, SBS-3 was the third in a series of business communications satellites, while Telesat Canada's Anik C-3 was the fifth of a series of satellites that were to provide domestic communications services for Canada.

The SBS-3 spacecraft was manufactured by Hughes Aircraft Company, El Segundo, California. (SBS-1 and SBS-2 were launched by NASA's Delta rocket.)

SBS was a private communications company with headquarters in McLean, Virginia. The firm is owned by subsidiaries of Aetna Life and Casualty, Comsat General Corporation, and IBM.

SBS-3 was to be the first spacecraft launched out of the Shuttle cargo bay. It was to be deployed on the sixth orbit, about eight hours after liftoff, when the orbiter was over the Atlantic Ocean. The Anik C-3 spacecraft was to be released on the second day of the mission, on about orbit 22, while Columbia was over the Pacific Ocean near Hawaii.

SBS-3 was designed to provide all-digital communications and features time-division, multiple-access techniques for efficient use of satellite transmission communications.

The satellite was 2.1 m (7 ft) in diameter and 6.4 m (21 ft) tall when deployed in orbit. The exterior surface of the satellite was covered with approximately 14,000 solar cells that generated 1,000 watts of dc power. An onboard power subsystem, including rechargeable batteries, powered the satellite's communications subsystem, including 10 operational transponder channels. Redundant traveling-wave-tube amplifiers provided a transmit power of 20 watts for each channel.

Three general types of services were provided by SBS:

- Communications Network Service which consisted of high-capacity private networks for all-digital integrated transmission of voice, data, video, and electronic mail among an SBS customer's widely dispersed facilities in the United States.
- Message Service I, which was a high quality, economical long distance service for businesses and a second version, Message Service II, for residential customers.
- Spare Transponder Service, which was an offering of spare satellite capacity for communications firms, broadcasters, and cablecasters using the only Ku-band transponder capability offered by a U.S. carrier.

SBS-3 weighed about 3,277 kg (7,225 lb) when ejected from the payload bay.

Telesat Canada's Anik C-3 communications satellite was launched from the bay of the orbiter Columbia on the second day of the STS-5 mission. It joined four other operational Anik communications satellites in geosynchronous orbit.

The C-series satellites were the most powerful domestic satellites in commercial service until the latter half of the decade.

The satellite service of Telesat Canada was the principal means of providing modern voice, message, data, facsimile, and broadcast service to remote and northern parts of Canada. The satellite linked complement and augment the terrestrial communications networks and provided a large measure of system diversity to the terrestrial carriers.

The Anik C-3 satellite was the first in a series to provide rooftop-to-rooftop transmission of integrated voice, video and data communications for Canadian businesses, carry newly-licensed Canadian pay TV, and other broadcast services.

Anik C-3 weighed about 632 kg (1,394 lb) in geosynchronous orbit. Its solar cells produceed more than 1,100 watts of dc electrical power to operate the spacecraft's systems. The satellite was 2.1 m (7 ft) wide and 6.4 m (21 ft) tall when fully deployed. The spin-stabilized Anik C-3 operated in the high-frequency radio bands, 14 and 12 GHz with 16 transponders.

1982

The combination of higher transmission power (from 15-watt output tubes) and the 14/12 GHz bands allowed the use of small 1.2 m (3.9 ft) dish antennas in places, such as home rooftops and high density office buildings.

Anik C-3's antenna coverage included virtually all of populated Canada with four contiguous spot beams serving the western, west-central, east-central, and eastern regions of the country. Telesat's customers were able to choose regional, half or whole nation coverage, depending on their needs.

The spacecraft was built under contract by Hughes Aircraft Company, El Segundo, California.

Telesat Canada has headquarters in Ottawa, Ontario, Canada.

Project Results — Launched at 7:19 a.m. EST, November 11, 1982, from Complex 39, Pad A, Kennedy Space Center and returned at 6:33 a.m. PST (9:33 a.m. EST) November 16, 1982, at Edwards Air Force Base, California. Total mission time was 5 days, 2 hours, 14 minutes, and 25 seconds. It was the first operational mission of a shuttle flight. The crew included Vance Brand, commander; Robert Overmyer, pilot, and Joseph Allen and William Lenoir, Mission Specialists

The deployments from the payload bay into Earth orbit of the two communications satellites — Satellite Business Systems' SBS-3 and Telesat Canada's Anik-3 — were smooth. In a public telecast from their Shuttle orbiter Columbia, the crew displayed a sign: "Ace Trucking Company — We Deliver."

Astronauts Allen and Lenoir deployed SBS-3 from Columbia's payload bay into space at 3:17 p.m. EST, November 11, 1982, and Anik C-3 at 3:24 p.m. EST, November 12, 1982. The deployments were preceded by about six hours of regularly updated computations on Columbia's orbital parameters — altitude, velocity, inclination, etc. This information was relayed to the private SBS control center in Washington, D.C., and to Telesat Canada's Anik control center in Ottawa.

Each center provided NASA's Mission Control Center at the Johnson Space Center, Houston, Texas, with refined payload insertion information which Mission Control passed on to the STS-5 mission specialists, Allen and Lenoir. Pilot Overmyer then oriented Columbia so that its right wing pointed down toward Earth and its payload bay door faced opposite to Columbia's direction of movement.

Then, Lenoir and Allen entered commands into a computer. These commands first opened the clam-shell-like thermal shield of the satellite. This shield protected the satellite from temperature extremes in the open cargo bay. Then, they rotated a turntable that imparted a 50 revolution-per-minute spin to the satellite and its attached Payload Assist Module (PAM). The spin stabilized the satellite and prevented excessive heating or cooling in space. PAM was designed to propel the satellites deployed from low-Earth orbit to an elliptical transfer orbit. Finally, explosive bolts that released a Marman clamp holding down a powerful spring were fired, freeing the spring, and pushing the satellite away from Columbia at a rate of about 1 meter (3 feet) per second.

At this point, control of the satellite shifted to the owner. Brand and Overmyer maneuvered Columbia from a 184-statute-mile-circular orbit to an oval 184-by-201-mile orbit. They rotated Columbia's well-protected belly toward the satellite to protect its windows from the blast of the PAM's solid fuel rocket motor.

When Columbia was about 25 kilometers (16 statute miles) above and 31 kilometers (19 miles) ahead of SBS-3, the satellite was considered clear. The satellite's control center on Earth triggered PAM to blast the satellite into a transfer orbit with an apogee (high point) of 35,680 kilometers (22,240 miles) above Earth. Later, the control center fired the satellite's apogee-kick motor at apogee to circularize the orbit at 35,680 kilometers over Earth's equator. Between the PAM and apogee-kick motor firings, Brand and Overmyer again circularized Columbia's orbit to its original altitude of 184 miles.

Three Shuttle Student Involvement Project (SSIP) experiments were conducted on STS-5. SSIP is a joint venture of NASA and the National Science Teachers Association (NSTA) aimed at stimulating the interest of high school students toward careers in science and engineering. Experiment development and other costs associated with winning entries in the contest were paid for by corporate or individual sponsors.

Surface tension convection was the subject of an experiment by D. Scott Thomas of Johnstown, Pennsylvania. Surface tension is described by Thomas as "the skin on the surface of a liquid." Convection, the pattern of circulation of a liquid when heated, occurs in this skin. However, on Earth, surface tension convection is largely masked by gravitational convection in which heated liquid rises and colder liquid falls. In the near zero gravity of space, gravitational convection is absent, permitting improved observation of surface tension convection. In the experiment, a video camera recorded convection of heated oil in pans of different diameters, in liquids at varying depths and at nonuniform heating rates. Thomas' corporate sponsor was the Thiokol Corporation.

Reaggregation in the near zero gravity of space of cells of Porifera Microcione sponges was the subject of an experiment by Aaron K. Gilette of Winterhaven, Florida. In seawater on Earth, the sponge cells reassemble themselves into perfect sponges. Gilette wanted to determine how the absence of gravity affected such formation. Sponge cells were carried aboard Columbia in bags of seawater from which the calcium and magnesium ions that trigger formation of the sponges had been removed. At different times, calcium and magnesium ions and later a fixative were released into the bags. The experiment added to information about the cellular communication process that causes separated sponge cells to group together to form sponges. Gilette's corporate sponsor was Martin Marietta Aerospace.

An experiment by Michele A. Issel of Wallingford, Connecticut, was designed to determine whether geometrically perfect crystals of triglycine sulphate can be grown in microgravity. On Earth, malformations attributed to gravity's pull develop in the crystals during growth. The experiment was expected to provide information useful in future commercial processing of materials in space. Ms. Issel's corporate sponsor was the Hamilton Standard Division of United Technologies Corporation.

The metal-mixing experiment in the near zero gravity of space, conducted on STS-5, was a Getaway Special purchased by the Ministry of Research and Technology, Federal Republic of Germany. It involved periodic X-rays of molten mixture of mercury and gallium to observe the effects of microgravity on dispersion of mercury droplets into gallium, particle movement due to convection, and other properties. On Earth, molten mercury separates from molten gallium. The main purpose of this experiment was to test a selfoperating, transparent oven and X-ray unit. The Federal Republic of Germany reserved 25 Getaway Specials.

"Getaway Special" was the popular name for the NASA Space Transportation System's Small Self-Contained Payload Program. Individuals or organizations could purchase a Getaway Special for a safe, scientific, and peaceful experiment in space. Getaway Specials were flown on a space-available first-come-first-served basis and cost from $3,000 to $10,000 U.S. dollars.

Major Participants

NASA Headquarters

Lt. Gen. James A. Abrahamson	Associate Administrator for Space Flight
L. Michael Weeks	Deputy Associate Administrator for Space Flight
Joe H. Engle	Assistant Associate Administrator for Space Flight (Space Transportation)
Isaac T. Gilliam IV	Assistant Associate Administrator for Space Flight (Policy)
Richard J. Wisniewski	Assistant Associate Administrator for Space Flight (Institutions)
Robert E. Smylie	Associate Administrator for Space Tracking and Data Systems

Anik C (left) and SBS-C (right) at Kennedy Space Center.

Dryden Flight Research Facility

John Manke	Facility Manager
Gary Layton	Shuttle Project Manager

Johnson Space Center

Glynn S. Lunney	Manager, Space Shuttle Program
Arnold D. Aldrich	Manager, Space Shuttle Orbiter Project Office
George W. S. Abbey	Director of Flight Operations
Aaron Cohen	Director of Engineering and Development
Lynwood C. Dunseith	Director of Data Systems and Analysis

Kennedy Space Center

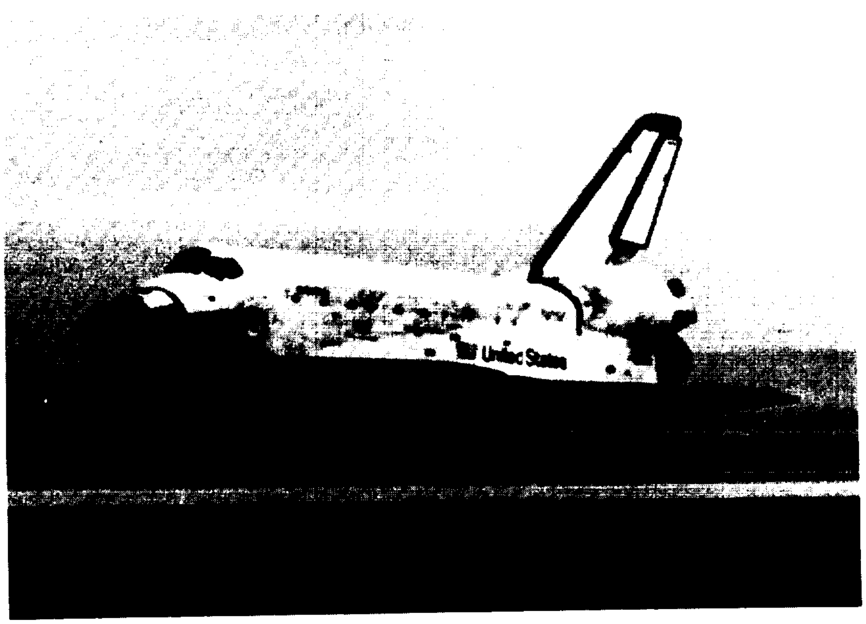
Robert H. Gray	Manager, Shuttle Projects Office
John J. Neilon	Manager, Cargo Projects Office
Thomas E. Ustman	Director, Shuttle Operations/ Technical Support
Thomas S. Walton	Director, Cargo Operations
Alfred D. O'Hara	Director STS Processing

Marshall Space Flight Center

Robert E. Lindstrom	Manager, MSFC Shuttle Projects Office
James E. Kingsbury	Director, Science and Engineering Directorate
James B. Odom	Deputy Manager for Production and Logistics, MSFC Shuttle Projects Office and Acting Manager, External Tank Project
George B. Hardy	Deputy Manager for Development, MSFC Shuttle Projects Office
Lawrence B. Mulloy	Manager, Solid Rocket Booster Project, MSFC Shuttle Projects Office
Lowell K. Zoller	Manager, Engineering and Major Test Management Office, MSFC Shuttle Projects Office
Judson A. Lovingood	Manager, Space Shuttle Main Engine Project, MSFC Shuttle Projects Office

Marshall Space Flight Center

Robert E. Lindstrom	Manager, MSFC Shuttle Projects Office
James E. Kingsbury	Director, Science and Engineering Directorate
James B. Odom	Deputy Manager for Production and Logistics, MSFC Shuttle Projects Office and Acting Manager, External Tank Project
George B. Hardy	Deputy Manager for Development, MSFC Shuttle Projects Office
Lawrence B. Mulloy	Manager, Solid Rocket Booster Project, MSFC Shuttle Projects Office
Lowell K. Zoller	Manager, Engineering and Major Test Management Office, MSFC Shuttle Projects Office
Judson A. Lovingood	Manager, Space Shuttle Main Engine Project, MSFC Shuttle Projects Office



STS-5 touches down at Edwards Air Force Base, California.

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